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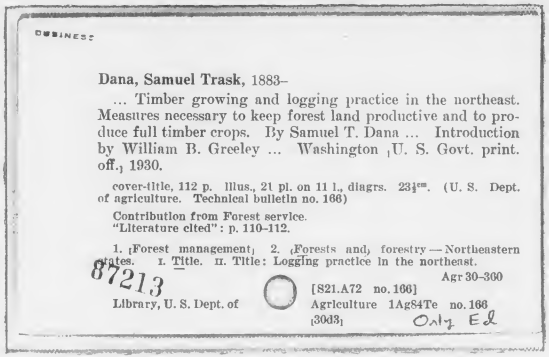

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TECHNICAL BULLETIN No. 166 MARCH, 1930

TIMBER GROWING AND LOGGING PRACTICE IN THE NORTHEAST

MEASURES NECESSARY TO KEEP FOREST LAND PRODUCTIVE AND TO PRODUCE FULL TIMBER CROPS

BY

SAMUEL T. DANA

Formerly Director, Northeastern Forest Experiment Station
Forest Service

INTRODUCTION BY

WILLIAM B. GREELEY

Formerly Forester, Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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TECHNICAL BULLETIN No. 166 MARCH, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

TIMBER GROWING AND LOGGING PRACTICE IN THE NORTHEAST[1]

By SAMUEL T. DANA, formerly *Director, Northeastern Forest Experiment Station,*[2] with Introduction by WILLIAM B. GREELEY, formerly *Forester, Forest Service*

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INTRODUCTION

Forestry in the United States is no longer merely a theory or a subject for discussion; it has gotten down to concrete things in the woods. Nor is the growing of timber confined to public lands; it is gradually making headway on land in private ownership. It is becoming an art of land management, expressed in practical measures for protecting forest growth from fire and other destructive agencies, for logging timber so as to produce a new crop of wood, and for planting forest trees on cut-over areas. The value of timber, along with other economic considerations, is causing landowners more and more widely to study the possibility of profitable reforestation. These developments have created a general demand for information on the timber-growing methods which are adapted to the various types of forest growth in the United States, and on what these methods will cost.

Timber culture, like the growing of farm crops, is necessarily governed in any country by the soil and climate, by the requirements

[1] This bulletin is based in large part on field studies and manuscript reports by R. C. Staebner, forest inspector, and Raphael Zon, director, Lake States Forest Experiment Station. Acknowledgment is also made of the hearty cooperation received from representatives of forest schools and State forestry departments, timberland owners, and many others.

[2] The Northeastern Forest Experiment Station is maintained at Amherst, Mass., in cooperation with the Massachusetts Agricultural College.

of the native forest trees, and by the national economic circumstances. Lessons may be drawn from the experience of other countries, as the United States has drawn upon the forestry practice of Europe, but profitable methods of growing timber, particularly under the wide range of forest types and economic conditions in the United States, can be evolved only from our own experience and investigation, region by region. Hence, to meet the demand for information on practical ways and means of growing timber profitably in the various parts of the United States, it is important that the results of of our own experience and investigation to date be brought together and set forth in the clearest possible way.

This the Forest Service has attempted to do in a series of publications dealing with the 12 principal forest regions of the United States. The information presented has been gathered from many different sources, including the experience, as far as it was obtainable, of landowners who have engaged in reforestation. An effort has been made to bring together all that any agency has yet learned or demonstrated about the growing of timber in the United States; and the results have been verified as far as possible by consultation with the forest industries, State foresters, and forest schools. These publications thus undertake to set forth, in a simple form, what are believed to be the soundest methods of reforestation as yet developed in our common experience and study in the United States.

Necessarily, the Forest Service claims no finality for the measures proposed. Timber growing in every country has come about through a gradual evolution in industrial methods and the use of land. All too little is yet known of the best methods of growing timber under American conditions. As time goes on, research and practical experience will add greatly to the success and certainty of the measures carried out in our woods; just as American agriculture has steadily become more highly developed or just as our manufacturing processes have been perfected through experience and study. But we know enough about growing timber now in the forest regions of the United States to go right ahead. Believing that the forest landowners of the United States are now ready to engage in timber growing on a large scale, the Forest Service has endeavored to place before them in concise terms the best suggestions and guides which the experience of this country to date affords.

In these publications the measures proposed for a particular forest region have been arranged in two general groups. The first includes the first steps, or the minimum measures based on local physical conditions, that are needed to prevent timber-bearing lands from becoming barren. These measures, in which the prevention of fire is of outstanding importance, represent broadly speaking the least that must be done and the lowest cost that must be incurred to keep forest lands reasonably productive. While influenced in some cases by the economic conditions in the region, they have been worked out primarily from the standpoint of the landowner who may not be ready to engage in real timber culture but who wishes to prevent cut-over tracts unsuitable for any purpose except timber growing from becoming a liability on his hands. Except within certain limitations, which are discussed in dealing with particular regions, the Forest Service believes that these first steps or minimum measures should

be speedily applied to all of the forest lands in the United States, and that public policy should encourage their universal application in such ways as protection from fire and the adjustment of forest taxation to the business of timber growing.

The second group of proposed measures constitutes what may be called the desirable forestry practice in the region concerned as far as our knowledge and experience to date enable us to determine it. These measures are designed to grow reasonably complete crops of the more valuable timber trees, making full use of the real productive capacity of the land. The recommendations are addressed primarily to the landowner who wishes to use his property up to its full earning power for timber culture. It is impossible to frame any general set of measures of this character that are adapted to the individual needs of particular holdings or industrial establishments. This is true particularly of forest regions like the Northeastern States, which include a great variety of local situations both in the types of growth and in economic circumstances. Hence, in presenting this group of suggested measures, the Forest Service has attempted only to draw the broad outlines of the more general and fundamental things, with illustrative methods of forest practice. The details of intensive forestry, like the details of intensive agriculture or engineering, call for expert survey in working out the plans and methods best adapted to a particular tract of land or a particular business. One of the most important features of expert planning for the management of a particular forest property is to devise not only woods operations that will produce full crops of timber but also a scheme of logging that will afford a continuous yield of products desired, in order that sustained earnings may be realized or a sustained supply of raw material made available.

In some cases it is not practicable to draw a hard and fast line between the first steps that will maintain some degree of productiveness on forest land and the most intensive measures that will bring the quantity and quality of wood produced up more nearly to an ideal management. Gradations between the two general groups of measures are inevitable. The Forest Service has not attempted, therefore, to deal with the two general types of forest practice as wholly separate and distinct, but has rather endeavored to present a commonsense and practical résumé of the various steps in timber growing in the form that will be most helpful to the man in the woods. The bulletins have been written for the landowner and the lumberman rather than for the technical forester. Their purpose is to put the main ideas into such form as, in view of the specific needs and problems of each region, will be most useful to the man to whom timber growing is a concrete business and logging problem. At the same time it is hoped that they will have value for the everyday reader who is interested in forestry as an important phase of land use in the United States and in the public policies designed to bring forestry about.

It is impossible for publications necessarily dealing in broad terms with the conditions existing over large regions to attempt any brass-tack conclusions on the cost and returns of timber growing. The approximate cost of the measures advocated is indicated as far as practicable and the extent to which they may be of benefit in con-

nection with logging operations, but no attempt is made to segregate the items chargeable to harvesting one crop of timber from those which should be regarded as invested in a following crop. Conservative estimates of the future yields of timber that may be expected under the various practices recommended are given where the facts available appear to warrant them; but no forecasts of the profits to be derived from commercial reforestation are attempted. The financial aspects of forestry can not be dealt with in general terms. Here again expert advice must deal with the situation and with the problems of the individual forest owner or manufacturer.

As a broad conclusion, however, with the exception of limited situations which are dealt with region by region, the Forest Service has tremendous faith in the commercial promise of timber growing to American landowners. The law of supply and demand is working steadily to create timber values which in large portions of the United States will pay fair returns on forestry as a business. The economic history of other countries which have passed through a cycle of virgin-forest depletion similar to that which the United States is now traversing points to the same inevitable conclusion. The time is fast approaching when forestry, and forestry alone, will supply the enormous quantities of wood demanded by American markets. The fundamental laws of business must in the nature of things so operate as to enable the markets of forest products to be supplied at a profit to the grower of timber. The returns already being obtained from this form of land employment at many points in the eastern United States show plainly enough that this relationship between the value of timber and the cost of producing it is already coming about to a marked degree.

To the men who own forest-producing land in the United States, or are engaged in industries which require raw material, forestry now offers a commercial opportunity. Satisfactory returns from forestry can not be promised in sweeping terms any more than returns from the manufacture of lumber or paper. But the opportunity for a profitable employment of capital and business talent in the growing of timber merits the same consideration and the same expert guidance as industrial opportunities in the conversion of timber. This applies with special force to the commercial institutions in the United States which have made large capital investments in manufacturing plants and distributing organizations, dependent for their maintenance upon a future supply of forest-grown material. It applies equally to the owners of land in large tracts or farm wood lots, the earning capacity of which lies solely in the growing of trees, and which without tree growth will become either a doubtful asset or an outright liability.

The Forest Service earnestly asks the forest landowners of the United States to determine for themselves, with the same care with which they would approach any other business problem, whether timber growing does not offer a commercial opportunity which should be grasped. It commends this series of publications to them, not as a complete or authoritative scheme that can forthwith be followed with profit in their own woods, but as a starting point in utilizing the opportunities that forestry may hold out.

W. B. GREELEY.

THE FORESTS OF THE NORTHEAST

FOREST AREAS

The "Northeast," as the term is used in this bulletin, includes the six new England and the three Middle Atlantic States. Practically all of this territory was originally covered with forests, somewhat more than half of which were gradually cleared away in the course of agricultural development. Since the Civil War, however, and more particularly since 1880, there has been a steady reversion of the poorer farm lands to forest. In the 40 years from 1880 to 1920 the area of improved farm land decreased 30 per cent, and the process still continues. The decrease has ranged from a minimum of 12 per cent in Pennsylvania to a maximum of 70 per cent in New Hampshire. (Fig. 1.) Nearly all of this land is, or will be sooner or later, restocked with trees.

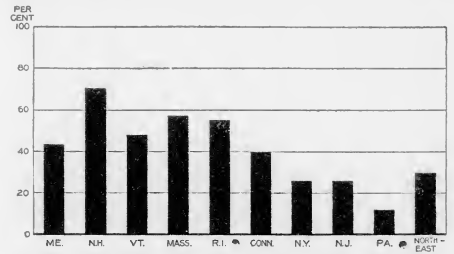


FIGURE 1.—Decrease in the acreage of improved farm land in the Northeast, 1880–1920. (Figures from United States census reports)

The present forest areas in the Northeast, as estimated by the respective State foresters, are given in Table 1. These areas can be expected to increase with the continued abandonment of farm lands.

TABLE 1.—*Forest areas in the Northeast, by States, 1927*

State	Forest area	Ratio of forest area to total land area of State	State	Forest area	Ratio of forest area to total land area of State
	Acres	*Per cent*		*Acres*	*Per cent*
Maine	15,000,000	78	New York	12,100,000	40
New Hampshire	4,600,000	76	New Jersey	2,100,000	44
Vermont	3,800,000	65	Pennsylvania	13,000,000	45
Massachusetts	3,300,000	64			
Rhode Island	300,000	44	Total	55,500,000	53
Connecticut	1,500,000	49			

The Northeast is the most densely populated and at the same time one of the most extensively forested regions in the United States. Although embracing only 5 per cent of the total land area of the country, it includes 28 per cent of the population and 12 per cent of the forest area. (Pl. 1.) The population is chiefly urban and industrial in character, the 24 per cent that is rural constituting the smallest percentage for this class in any group of States in the country.

More than 50 per cent of the region as a whole, and more than 70 per cent of New England, is forest land, as against 25 per cent for the entire country. Extensive areas of forest are found throughout the region, and not only in the so-called "wild-land" sections. Even in so densely populated a State as Massachusetts, there are towns within 50 miles of Worcester that have 90 per cent of their area in forest. Because of the relatively small agricultural development of the region as a whole, farm wood lots constitute only 28 per cent of the total forest area. They are, however, an important part of most farms, particularly in New England, where their total area is greater than that of improved land. In addition, there is a considerable area on farms classed as "other unimproved land," much of which is doubtless already bearing an inferior tree growth or is capable of being used for forest production.

The relations between forest land, improved farm land, and other land (towns, roads, barren mountain tops, salt marshes, etc.) are shown by States in Figure 2. The farm wood lots are of relatively greater importance from the standpoint of forest management than their actual area would indicate. Their usual occurrence in relatively small tracts reduces the danger from fire, and proximity to good markets permits them to be handled by more intensive methods than can be employed in the more remote sections.

The large proportion of forest land, as well as the market for forest products offered by the dense population and the high industrial development, points to timber growing as an essential factor in the prosperity of the region.

FOREST REGIONS AND TYPES

The Northeast includes five distinct forest regions. These are shown roughly on the accompanying map. (Fig. 3.) Since changes in region are due to broad changes in climate, the actual boundaries are not, of course, so sharp as those indicated. Instead, adjacent regions are always separated by transition zones of varying width in which trees characteristic of both regions are common. Altitude as well as latitude has a marked influence on climate and therefore on the character of the forest. In the mountains well to the south, for example, such typically northern trees as spruce and yellow birch are found.

Forest regions are divided into forest types, each of which consists of a characteristic combination of species. Changes in type are due to minor differences in climate and still more to soil differences. For this reason the boundaries between forest types are much more distinct than those between forest regions. In the Northeast the varied topography and the glacial soils characteristic of the bulk of the territory give rise to frequent changes in the composition of

the forest, so that several types may occur in an area of a few square miles. It would therefore be impossible to show accurately the distribution of types in the different forest regions except on a very large scale map, even if the detailed information necessary for this were available.

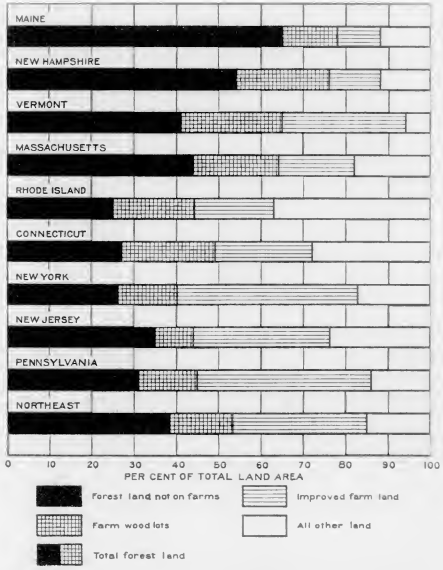


FIGURE 2.—Forest land, improved farm land, and other land in the Northeast, by States, in percentages of total land area

Forest types in turn may be subdivided into any number of stands, which are simply aggregations of trees growing on a limited area with substantial uniformity not only in composition, but in age, distribution, density, and site. For really intensive forest management the stand is the unit of treatment.

In this bulletin it will obviously be impossible to suggest methods for the handling of individual stands, or even of all the 30-odd

forest types which are now recognized by foresters in the Northeast (*3, 38, 39*)[3]. Many of these types are of minor importance, and the differences between closely related types are often small. Attention will therefore be concentrated on those of major importance from the standpoint either of commercial value or of area covered.

The recommendations made are based as far as possible on the experience of timberland owners in the actual management of their forest lands. Comparatively little, however, has so far been done in many forest types, and on few areas have accurate records been kept of the operations performed, the costs involved, and the results obtained. Definite figures as to what may be expected from a given

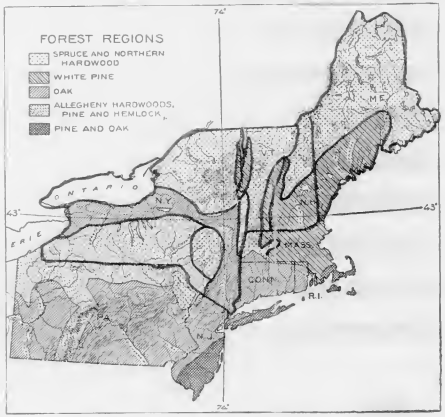
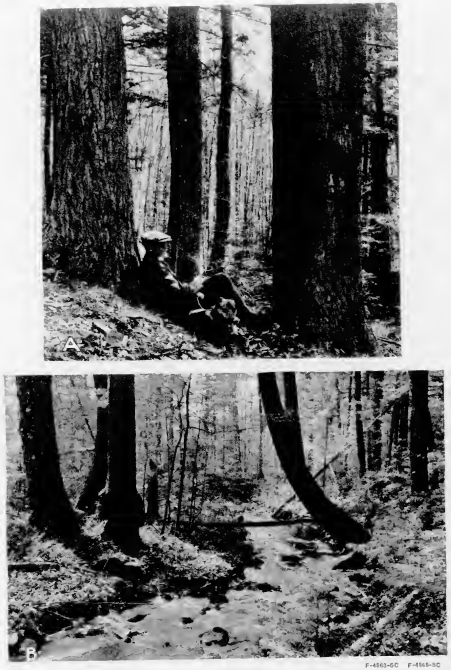


FIGURE 3.—Forest regions of the northeastern United States

treatment can not, therefore, be given so often as might be anticipated in a part of the country where so much attention has been paid to forestry as in the Northeast. Moreover, in dealing comprehensively with so large and varied a forest area the recommendations are necessarily somewhat general in character, whereas silviculture is essentially local. They should, therefore, be looked upon more as a guide than as definite instructions, and should often be modified when applied to specific tracts.

More specific information and advice on the handling of forest lands can be obtained from State foresters, extension foresters, and

[3] Italic numbers in parentheses refer to "Literature cited," p. 110.



VETERAN WHITE PINE STANDS IN MASSACHUSETTS

These two stands in the Harvard Forest at Petersham represent typical pure pine (A), and mixed white pine and hardwoods virgin growth (B) of the white pine region.

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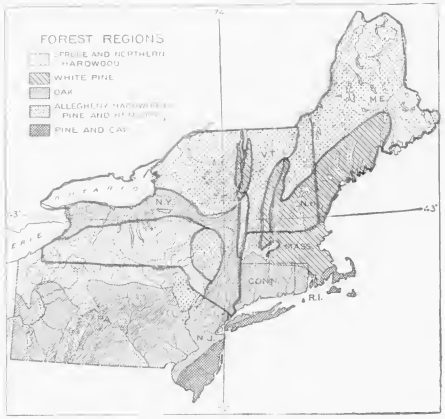

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A, Variation of type with altitude. A typical view in the spruce and northern hardwoods region of the Adirondack Mountains, showing the northern hardwoods type at the medium elevations and the spruce-slope type at the upper elevations. B, a skidway of spruce logs in Hamilton County, N. Y., piled ready for hauling.

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FOREST UTILIZATION AND LOGGING PRACTICE

The forests of the Northeast have been subjected to almost continuous cutting since 1623, when the first sawmills were erected. In 1840, the first year for which figures are available, 65 per cent of the lumber production of the entire country came from this region. In 1927 Maine led all other States in wood-pulp production, with New York, Pennsylvania, and New Hampshire third, fifth, and sixth, respectively. Other industries use large quantities of wood for fuel, railroad ties, posts, poles, mine timbers, turned articles, veneer, furniture, cooperage, and other products.

The forest and wood-using industries have always played an important part in the economic life of the Northeast. The forests of the region are, however, no longer able to meet the timber requirements. Maine, New Hampshire, and Vermont are now the only States in the region which still produce from their own forests as much lumber as their industries use. The other six States import from 5 to 50 times as much lumber as they cut. These imports come largely from the South and the Pacific Northwest. Clearly, the exhaustion of the virgin forests in these regions will produce a ready market for all the local timber that can be grown under better methods of forest management.

The logging practice so far followed in the utilization of both virgin and second-growth forests has had little relation to timber growing. Methods of cutting have ordinarily been chosen for their cheapness and effectiveness in getting out the logs, without particular reference to the future of the forest. Fortunately, the methods adopted have been much less destructive than those used in certain other part of the country.

In a typical logging operation of considerable size, the trees to be removed are first felled and cut into logs (*5*). This is usually done in the fall unless peeled pulpwood is desired, making it necessary to do the felling and peeling between the latter part of May and the middle of August. The logs are next dragged on the ground or hauled on small drays to the skidways along the main sled roads. This skidding is almost always done by horses, and very seldom by mechanical power. At the arrival of deep snow, skidding ceases, and the logs are hauled on heavy sleds to the waterway, railroad, or mill. This hauling may be done by horses, steam or gasoline log haulers, or caterpillar tractors. In those parts of the region where there is not enough snow to permit the use of sleds, the hauling is done with heavy wagons or trucks.

The network of roads and trails required for a logging operation of this sort is shown in Figure 4 (*27*). The main hauling road has a cleared width of at least 20 feet, the main yarding roads of 5 or 6 feet, and the minor skid trails of 2 or 3 feet. The skid trails, however, run up to twice the width when two horses are used or when drays are substituted for snaking. On the surface covered by the roads and trails practically all the seedlings and saplings already on the ground are destroyed. The damage is particularly marked with

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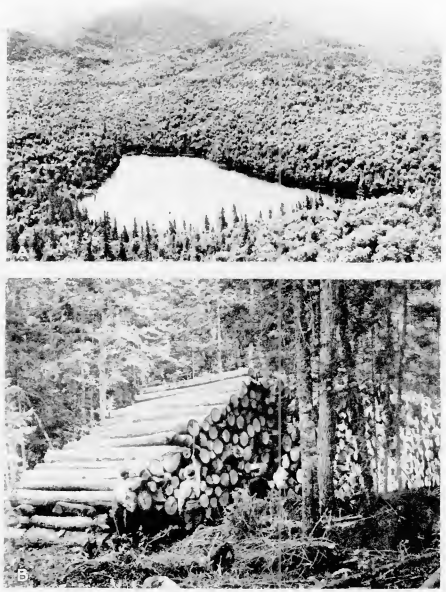

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The network of roads and trails required for a logging operation of this sort is shown in Figure 4 (*27*). The main hauling road has a cleared width of at least 20 feet, the main yarding roads of 5 or 6 feet, and the minor skid trails of 2 or 3 feet. The skid trails, however, run up to twice the width when two horses are used or when drays are substituted for snaking. On the surface covered by the roads and trails practically all the seedlings and saplings already on the ground are destroyed. The damage is particularly marked with

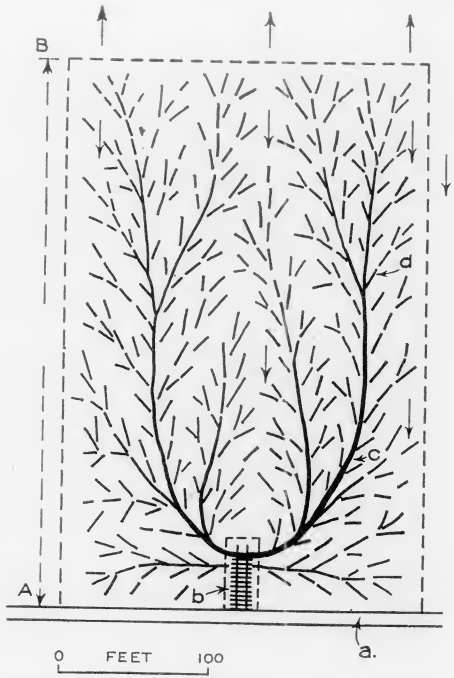

FIGURE 4.—A typical scheme of skidding-trail location, showing (*a*) main sled road, (*b*) skidway, (*c*) main skidding trail, and (*d*) secondary skidding trail. The arrows indicate the direction of the slope. (Reproduced by permission of the Yale School of Forestry.)

two-horse skidding. On the other hand, the tearing up of the soil in the skid trails probably makes a more favorable seed-bed for subsequent reproduction. The result is, therefore, not so much to denude the area as to change the composition of the forest and to set it back by the period required for the new reproduction to reach the size of the young growth destroyed.

On farm wood lots the method of logging is somewhat different. Here a portable sawmill is usually set up on the tract to be cut, and the logs are skidded or hauled directly to the mill. Each operation is limited to a few hundred thousand board feet. Except for the fact that there is no main hauling road, the system of skid trails and yarding roads is much the same as in the larger operations, and the damage to the young growth is similar.

In both types of operation, the degree of damage increases with the severity of the cutting. In what is virtually clear cutting—such as is often practiced for pulpwood, box boards, chemical wood, and fuel—the slash resulting from logging may cover as much as two-fifths of the area, the remainder of which is pretty thoroughly dissected by skid trails and roads. Such cutting has, however, become common only within the last 20 years. Up to that time, the limited market for small material made it more profitable to cull out only the larger trees, so that the entire cover was seldom removed at any one time.

On the whole, the logging practice followed in the Northeast has resulted in the deterioration rather than in the devastation of the forest. This is due largely to the fact that the climate and the soil are in general so favorable for tree growth, and the trees themselves so vigorous and aggressive, as to enable the forest to stand a good deal of abuse. It is a striking fact that where fire has been kept out, natural reproduction of some sort has ordinarily taken place; but the new stands have by no means always been well stocked or composed of desirable species. Such stands will not produce the highest yields of which the land is capable, nor will they meet the timber requirements of the region. Moreover, there are many other areas where the forest is in a deplorable condition and where its productive capacity has been greatly reduced.

Such really denuded forest land as occurs in the Northeast, and this probably aggregates several million acres, is attributable much more largely to fires than to logging. A single fire following cutting sometimes converts the burned-over area into a barren waste, and a second fire is fairly certain to do so. Some land of this sort will gradually revert through natural reproduction to forest growth of economic value, but the process will at best be slow, and in most cases planting will be necessary to restore the land to productivity within a reasonable time.

KEEPING FOREST LAND PRODUCTIVE

FIRE CONTROL

From what has already been said, it is clear that keeping forest land productive is primarily a matter of keeping out fire. Without fire control, devastation is not only possible but probable; mature timber is not safe from destruction, young growth is not likely to

reach maturity, and cut-over and denuded areas have little chance to restock. (Pl. 4.) With fire control, the maintenance of some kind of tree growth on forest land is reasonably certain. Marked deterioration may still result, but real devastation is unlikely. The importance of fire control as the first and most essential step in timber growing can, therefore, hardly be overemphasized.

Although this basic fact is now generally recognized in the Northeast, Table 2 indicates that the problem of adequate protection can not yet be regarded as satisfactorily solved. The figures for damage are particularly striking in view of the fact that they do not take into account the vast amount of intangible and indirect damage resulting from forest fires, such as decay of damaged timber, replacement of desirable species by less desirable but more fire-resistant species, soil deterioration and erosion, loss of wild life, uncertain stream flow, interrupted tourist traffic, and the like. Because of different standards in the gathering of statistics the figures for the different States are not entirely comparable.

TABLE 2.—*Number of forest fires, area burned, and degree of damage in the Northeastern States, annual average, 1916–1925*

State	Fires	Forest area burned		Total damage
	Number	*Acres*	*Per cent*	*Dollars*
Maine [1]	155	23,594	0.16	152,814
New Hampshire	608	4,894	.11	59,805
Vermont	94	1,229	.03	8,020
Massachusetts	2,990	18,129	.55	157,105
Rhode Island [1]	59	4,800	1.60	46,547
Connecticut	811	26,723	1.78	132,936
New York [2]	555	15,648	.13	29,682
New Jersey	881	63,910	3.04	300,618
Pennsylvania	2,143	153,821	1.18	497,642
Northeast	7,896	312,748	.56	1,385,169

[1] Records not complete for entire State prior to 1920.
[2] Records apply only to the so-called fire-protection area.

FIRE-CONTROL ORGANIZATION

Active participation by the State is essential in effective forest-fire control. The efforts of any individual owner or group of owners are seriously handicapped by the fact that fire recognizes no property lines, so that the carelessness of a single individual may endanger an entire community. Forest fires frequently require the rapid mobilization of large numbers of fire fighters, with the necessary supplies and equipment, and their control by some one in authority. Furthermore, "everybody loses when timber burns." These facts all emphasize the need of an organization which will be state-wide in scope and under public control.

There is some question as to whether such an organization should include scattered areas of wooded land in the more thickly settled districts. Such areas, as a rule, may be more properly classed as suburban property awaiting development than as true forest land, and their protection can well be left to the regular town or city fire department. With this possible exception, experience shows conclusively that the State department of forestry should be made

responsible for the prevention and suppression of all forest fires. This is now in effect throughout the Northeast, where the chief need of these departments is for ample authority and appropriations to discharge their responsibility effectively.

The usual and desirable practice of the State foresters is to place one man in complete charge of all fire-control activities, with such technical and clerical assistance as the size and importance of the job warrant. Under this man should be a permanent field force of district fire chiefs, each in charge of an administrative unit, or fire district. The boundaries of these districts may be determined by county, watershed, or other tactical lines, and will vary in size according to accessibility and degree of fire danger.

Each fire district should, in turn, be divided and subdivided into as many units as are necessary for good administration. In one State, for example, there are now four fire districts, in which the township is the next smaller division. For each township there is a town fire warden who reports directly to the district fire chief and who is assisted by one or more deputies. In another State there are three main divisions, each of which is divided by tactical lines such as roads, railroads, and streams into a number of "sections" in charge of section fire wardens. In each section are a number of town wardens, under whom, in turn, come "district" wardens. Political boundaries, however, are used for fiscal purposes only, and the fire-suppression units are organized without reference to town or county lines. In most States local arrangements are made so that temporary laborers, or "listed helpers," may be employed for fire fighting on short notice.

However the details of organization may vary in different States, it is essential that ultimate responsibility for the entire system rest with the State forester. He should have complete authority to appoint, control, and remove every member of the force from the district fire chiefs to the most subordinate local wardens. Lack of such authority is now one of the weakest points in the fire-control system in some parts of the Northeast.

The State organization should also be supplemented by the activities of private owners. Associations of timberland owners formed to provide more effective protection for the holdings of their members have been in existence in several States for years, and might well be more numerous. Educational measures and the maintenance of patrols and lookout towers, either alone or in cooperation with the State forester, usually constitute their chief activities. Additional patrols are often employed by individual owners for their own lands when the protection that the State can give is not regarded as adequate. All such efforts should, of course, be closely coordinated with those of the State forestry department, and it is essential that the district fire chiefs or other appropriate State officials have authority to exercise complete control over all fire-fighting operations.

FIRE PREVENTION

Complete prevention of all forest fires is obviously the most effective form of fire control. The fire that never starts does no harm. Attainment of this goal is a long way in the future, but more rapid progress toward it than is now being made should be possible. The

nub of the problem lies in the reduction of carelessness, which is the cause of at least 95 per cent of the fires in the Northeast.

Carelessness can be overcome most effectively by education and legislation. Many people do not realize what constitutes carelessness with fire in the woods or how disastrous the results of carelessness may be. (Pl. 3, A.) Measures to inform them are already an important part of the activities of most of the State forestry departments and timberland owners' associations. More might well be done in this direction, however, and in addition educational activities might well be made an integral part of the programs of such civic organizations as chambers of commerce, rotary clubs, and farm bureaus. Newspaper and magazine articles, talks, posters, stickers, and moving pictures are all useful forms of publicity.

Patrolmen perform a useful function in both fire prevention and fire detection. For both purposes they can be used to best advantage where most people are to be found in the woods, as along roads, trails, and fishing streams, and at camping places; and also in localities of unusual hazard, such as recently cut-over areas. By warning tourists and other travelers of the fire danger, by instructing them as to the safe use of fire, and by keeping track of their movements, patrolmen can be of great value in reducing the fire danger. In addition, they will often be able to extinguish, while small, any fires set by campers, smokers, and others. In general, the value of a patrolman is to be measured rather by the number of fires he prevents than by the number he extinguishes.

Educational measures should be supplemented by legislation providing penalties for carelessness with fire in any form and declaring anyone guilty of starting a forest fire, whether intentionally or not, responsible for civil damages caused thereby. In addition, the person causing a fire should bear the entire cost of its extinction. There should be a heavy criminal penalty for starting a forest fire maliciously.

The burning of brush or other material on or near forest land is responsible for 10 per cent of the total number of fires. The danger from this source can be lessened either by prohibiting brush burning entirely during a specified fire season or by requiring a permit for burning during the season. If permits are used, they should be procurable through local officials but should be subject to suspension or revocation at any time by the State forester, who should also have authority to stop the issuing of all permits during periods of unusual hazard. Permits should ordinarily be issued for a single day only. They may also well contain restrictions as to the conditions under which the burning may be done; such for example as allowing burning only after 4 p. m., when decreasing temperature and increasing humidity usually lessen the danger of spread; or only if sufficient assistance is at hand to keep the fire under control. The system of requiring brush-burning permits is now generally in effect throughout the Northeast, but its effectiveness could be considerably increased through greater care in the issuing of permits by local officials and through closer supervision of this function by the district fire chief.

Camp fires and smoking are together responsible for nearly 20 per cent of the total number of fires. Camp-fire permits have proved effective in decreasing fire danger and should be generally required

in the wild-land sections of the State. Provision should be made so that travelers can obtain permits with as little difficulty as hunting and fishing licenses, and the permits should be subject to suspension or revocation by the State forester at any time. In most of the Northeastern States the governor already has authority to suspend the hunting or fishing season, and in a few to close the woods completely to such classes of persons and for such periods as he may designate. The good results obtained from such suspensions during the last few years have shown the desirability of making the practice general.

Railroads not burning oil are now almost universally required to use adequate spark arresters and to keep their rights of way clear of inflammable débris. In several States the railroads are permitted, subject to the approval of the State forester or the public utilities commission, to establish fire lines immediately adjacent to their rights of way; and in a few States the State forester has authority, during dry periods and in dangerous localities, to require that gasoline speeders patrol the tracks following each train. These latter provisions are desirable and might advantageously be adopted by those States where they do not now exist. The fact that 32 per cent of the forest fires in the Northeast during the 10 years from 1916 to 1925 were due to railroads indicates the importance of taking every precaution to reduce the loss from this source.

Both portable and permanent sawmills operating in the vicinity of forest land should be required, as is now generally the case, to use adequate spark arresters and to clear up all inflammable débris within a radius of 150 feet of the mill. Mill operators and loggers can do much to prevent fires by stopping all smoking by their employees at the mill or in woods during periods of exceptional danger.

Stricter enforcement of the forest-fire laws would help greatly in reducing the number of fires. This requires not only readiness on the part of the fire wardens to bring charges in all cases where there is sufficient evidence, but also, on the part of local prosecuting officials, greater cooperation in obtaining convictions than has sometimes been accorded. A person or corporation actually convicted of breaking the law is far less likely than before to repeat the offense, and serves as a healthy warning to others. In general it is true that from the standpoint of fire prevention there is less need for the enactment of new legislation than for the strict enforcement of that already on the statute books. Much progress has recently been made in this direction, but for the Northeast as a whole both education and law enforcement deserve much more attention than they have so far received.

DETECTION AND SUPPRESSION OF FIRES

Promptness in detecting and suppressing forest fires is next in importance to prevention. A few minutes difference in the time of getting to a fire may make all the difference between a harmless smudge and a disastrous conflagration.

Fire lookout towers equipped with map, field glasses, alidade, and reliable telephone connections are an essential part of the detection system. They were first tried out in Maine as far back as 1908 and are now in general use throughout the Northeast. They are

particularly valuable in the more remote, less settled districts where discovery by other means is unlikely. Wherever feasible, they should be so located that every fire can be picked up by at least two towers. This will make it possible to determine much more accurately the exact location of the fire and will considerably increase the chances of prompt detection during hazy weather when the lookout's range of vision is greatly decreased.

All lookout towers, including those maintained in whole or in part by private owners, should be under the supervision of the district fire chiefs, to whom the watchmen should report by telephone at least once and preferably twice a day, in addition to reporting all fires as soon as they are discovered. These watchmen should be on duty at the towers throughout the day during the entire fire season and should, if possible, be men who are personally familiar with the region covered. The system has been well developed throughout the Northeast, where the main needs are now the filling in of occasional gaps and the perfecting of details of operation.

Patrolmen, as has already been indicated, often constitute an important means of fire detection. They should be used freely for this purpose in areas which are much frequented by travelers, which are not visible from a lookout tower, or where efficient telephone communication is not practicable. In many localities it is a great advantage to have patrolmen equipped with a portable telephone set so that they can report promptly any fire too large to handle alone. It is also desirable to encourage local residents and transients to act as a sort of volunteer patrol force by keeping a sharp watch for fires and reporting them at once to the proper official. In the more thickly settled districts where such cooperation has been well developed, reports of fires are received about as frequently from these sources as from lookout towers.

When a fire has been reported, the essence of efficient suppression lies in reaching it at the earliest possible moment with sufficient men adequately supplied with fire-fighting equipment. Except when caught in their earliest stages fires must ordinarily be fought by organized crews varying in size from a few men to several hundred. The local warden and the district chief must, therefore, be ready to mobilize at least a small crew at a moment's notice, and to supplement this initial force as rapidly as circumstances may demand. Promptness in responding to a call and in getting to the fire is the criterion of effective organization. Where settlement is sparse, this involves the construction and maintenance of sufficient roads and trails to make all parts of the forest reasonably accessible.

No arbitrary limit can be set as to the time within which all fires must be reached to prevent their getting beyond control. This varies greatly with the kind of forest and with the prevailing weather conditions. A lightning fire in a northern hardwoods forest during a moist spell may smoulder for hours before becoming dangerous. On the other hand, an escaped camp fire in the pine woods of southern New Jersey during a dry, windy spell may be completely out of control within five minutes. In general, it is important to reach every fire at the earliest possible moment, and as the hazard increases this becomes more and more essential.

It would be out of place in this bulletin to discuss in detail fire-fighting methods. Emphasis can, however, properly be laid on a

FOREST FIRE IN THE WHITE MOUNTAINS

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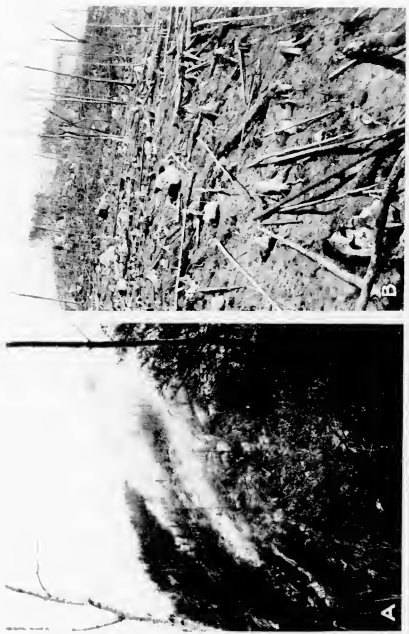

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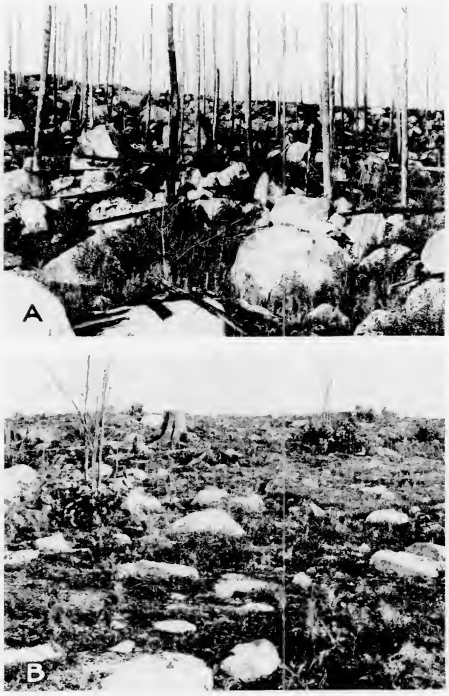

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THE PENALTY OF LACK OF ADEQUATE FIRE CONTROL

A, A double burn turns forest land to rocky waste; B, repeated fires have changed once thrifty forest into "barrens."

few facts of outstanding importance. First of all, it is poor policy to attempt to economize on men or materials. In the long run, it will prove cheaper to have too many rather than too few men, and to supply them with ample shovels, rakes, mattocks, axes, pumps, chemical extinguishers, and other equipment. As studies of the relation between weather conditions and fire hazard progress, it will become possible to gauge more accurately the danger under any given set of conditions, and hence the number of men really needed. In the second place, one man should be in complete charge of the entire force. Divided responsibility is as fatal in fire fighting as in military operations. Moreover, the man in charge can handle the situation best, particularly in large fires, by devoting his attention almost wholly to supervision rather than to actual fire fighting. Finally, a fire apparently under control should never be left without an adequate patrol until there is no question as to its being completely out. The establishment of effective fire lines, and the "mopping up" of places inside of these lines where the fire is still burning, are just as important as stopping the spread of the fire. Too many fires have come to life and caused serious damage after having been abandoned as no longer dangerous.

SAFETY IN SLASH DISPOSAL

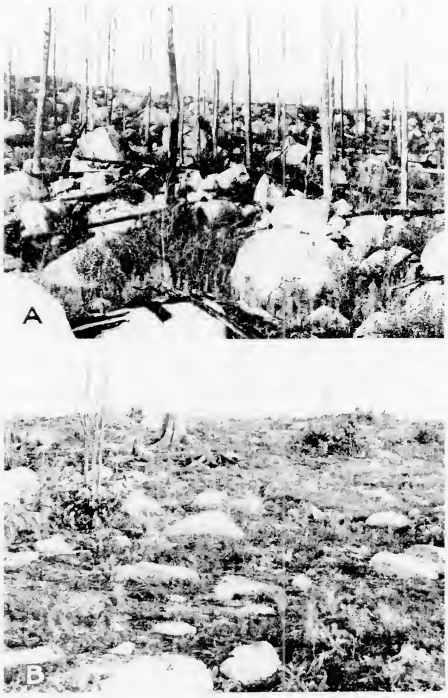
Slash, or the tree tops and branches resulting from logging operations, increases the fire danger and makes fire fighting more difficult. This condition persists for about 12 to 15 years in spruce and pine stands, and for 3 to 5 years where hardwoods have been cut. It takes about this length of time for decay to progress to the point where hazard from slash is practically eliminated. The most acute danger is in the early years—for softwoods, perhaps the first five; for hardwoods, perhaps the first two.

The increased danger also varies greatly with the amount of slash left. Because of the close utilization now common in the Northeast, the danger is much less there than in many other regions. Fuel wood, pulpwood, and acid wood are usually cut to top diameters of 2 to 4 inches, and even saw logs may be cut from trees of some species, such as northern white pine, to a top diameter of 5 or 6 inches. Even under the most favorable conditions, however, the smaller branches and twigs are never wholly utilized, so that logging operations always result in some slash and consequent increase in the fire danger.

Complete disposal of slash by piling and burning would be ideal from the standpoint of fire control. This method is already in use on softwood cuttings in the White Mountain National Forest and by a few private owners, and should be more generally adopted where the slash is heavy or the fire risk high.

The next most desirable method of slash disposal is lopping and scattering the branches of softwoods so as to bring them into contact with the ground and thus hasten decay. This is accomplished almost automatically with close utilization, so that in pulpwood operations, at least, the New York law requiring the lopping of softwood slash to a 3-inch diameter limit necessitates virtually no change in present practice. As for hardwood slash, decay is apparently no

PLATE 4



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more rapid with lopped than with unlopped material, except for a few species such as oak and chestnut (*44*).

The cost of either piling and burning or of lopping and scattering varies widely with the character and quantity of the slash and with the skill of the operator. In Massachusetts and New Hampshire the cost of piling and burning white pine slash has ranged from 50 cents to $1.50 for every thousand board feet of timber cut. On the White Mountain National Forest $1.50 a thousand is allowed for burning softwood slash as the logging progresses and $1 for lopping hardwood slash, or an average of about $1.25 a thousand in mixed stands. Experiments on a pulpwood operation in northern New Hampshire indicate a cost of about $1 a cord for piling and burning (*4*). On the Susquehannock State Forest in Pennsylvania, lopping and scattering the brush in an overmature stand of beech, birch, and maple cost from 50 to 70 cents a thousand.

High costs have usually been due to the fact that slash disposal was carried on as a separate operation from logging, or to the fact that the men handling it were not experienced or interested in the work. It has been the general experience in the national forests of the West, where brush disposal is almost universally required, that costs drop steadily as the men become more familiar with the work and as their interest and belief in it increase. Some operators state that the cost of brush burning is partially or wholly offset by the decreased cost of logging resulting from clearing up the area.

In the Northeast, where slash disposal has not been generally practiced, the average net cost by either burning or lopping could hardly be reduced in the near future to less than 75 cents a thousand and might easily run as high as $1 a thousand. This would mean an annual expenditure of $1,600,000 to $2,000,000 to handle the slash resulting from the present cut of lumber and pulpwood. The larger amount is nearly equal to the combined present fire damage and cost of fire control. Moreover, universal slash disposal would not permit any material reduction in the $1,000,000 now spent for control activities, nor would it eliminate all fire damage.

Considering the present close utilization of timber and the steadily increasing efficiency of State fire-control organizations, it is doubtful whether universal slash disposal, with its high cost, can be regarded as an essential feature of adequate fire control. Nearly all of the Northeastern States do, however, require the disposal of slash along public roads, and this requirement might well be extended to other especially dangerous places. Thus, all slash resulting from the building of public or private roads or from the construction of railroads should be piled and burned as the construction proceeds. In addition, strips on each side of regularly traveled roads or trails should be left uncut, or the slash resulting from cutting should be disposed of by piling and burning. Safe widths for such strips are 75 feet on main highways, 50 feet on secondary highways and logging roads, and 25 feet on trails.

The State forester should also be given authority to declare any unusually dangerous slash-covered areas a public nuisance, and to require the disposal of slash thereon. This would make possible the more adequate protection of small woods settlements and individual homes and of particularly exposed stands of valuable timber

menaced by adjacent slash. In lieu of slash disposal, he should also have authority to require adequate patrol of recently cut-over areas by their owners during periods of acute danger. Such patrol constitutes an effective means of protection during the particularly dangerous years immediately following cutting, and might well be much more generally provided by owners of their own volition than is now the case.

STANDARDS AND COST OF FIRE CONTROL

Estimates by State foresters as to the sums needed for protecting State (including county and town) and private forest lands from fire are compared in Table 3 with the amounts actually budgeted for protection purposes for the fiscal year 1926–27.

TABLE 3.—*Amounts budgeted for fire protection in the Northeast, 1926–27, and estimated cost of protection needed*

State	Amounts budgeted for protection				Estimated cost of protection	
	State and private	Federal	State, private, and Federal			
			Total	Per acre	Total	Per acre [1]
Maine	$205,760	$33,300	$239,060	$0.016	$450,000	$0.030
New Hampshire	62,000	9,940	71,940	.017	134,300	.031
Vermont	13,140	5,830	18,970	.005	78,800	.021
Massachusetts	63,000	12,630	75,630	.023	170,700	.052
Rhode Island	8,310	1,070	9,380	.034	14,400	.051
Connecticut	22,960	4,440	28,000	.019	60,000	.040
New York	213,745	28,750	242,495	.026	388,500	.041
New Jersey	75,620	6,100	81,720	.043	82,400	.043
Pennsylvania	172,605	29,120	201,725	.016	393,500	.030
Total	837,740	131,180	968,920	.018	1,772,600	.034

[1] Based on the area regarded as in need of organized protection, which does not always equal the total forest area of the State.

These figures do not include expenditures by private owners which are not made under the direct supervision of the State forester. The exact amount of such expenditures is not known, but would undoubtedly add considerably to the totals given. The estimates represent what in the best judgment of the State foresters is needed to provide a reasonable degree of protection at a reasonable cost and do not contemplate the elimination of all fires. In fact, the number of fires, although important, is of less significance than the area burned, which is generally regarded as a fair measure of the effectiveness of the protection organization.

Table 2 shows that the ratio of area burned to total forest area during the 10 years from 1916 to 1925 ranged from 0.03 per cent in Vermont to 3.04 per cent in New Jersey, with an average of 0.56 per cent for the entire Northeast. The maximum was perhaps reached in the anthracite section of Pennsylvania during the spring of 1923, when 734 fires burned more than 13 per cent of the total forest area in the section.

The difficulty of fire control varies so greatly with the character and accessibility of the forest, the extent to which and the way in which it is cut, the number of persons visiting it, the climate, and

other factors, that it is impossible to set any arbitrary relation between area burned and total forest area as representing a fair standard of efficiency under all conditions. The ratio of 0.1 per cent, which has been more or less discussed as such a standard, may be too high for the four northern States and too low for the five southern States. In Vermont, for example, the area burned is now kept down to 0.03 per cent of the total forest area at an annual cost of 0.5 cent an acre, while in the pine region of southern New Jersey it is estimated that an organization capable of reducing the burned area to 0.1 per cent would cost 40 cents an acre.

The estimated costs of protection represent the best judgment of their authors as to what is needed to attain a reasonable standard of efficiency, which is not necessarily the same under the widely varying conditions in the different States. In most States they would necessitate an aproximate doubling of the present budget. By the time this has been done, it is not unlikely that further increases will be regarded as desirable. As forest lands become more valuable and the importance of their protection more generally appreciated, there is little doubt that higher standards will be set and larger sums made available for their attainment.

PLANTING

WHERE PLANTING IS NECESSARY

Planting is essential for continued forest production:

On lands which have been so severely burned as to preclude natural reproduction. These probably comprise in the aggregate an area of several million acres and are chiefly lands which have been burned more than once.

On unburned cut-over lands where logging has not been followed by satisfactory natural reproduction. There is a relatively small area of such lands where tree growth is practically lacking, but a very large area where the natural reproduction is not satisfactory.

On abandoned farm lands which are reverting to forest slowly or not at all. These constitute a large area and offer one of the best opportunities for restoring once forested land to productivity.

PLANTING STOCK

Conifers are much more widely used for planting than hardwoods. This is largely because they thrive better under the adverse conditions which usually prevail on areas where planting is most necessary. As a result of repeated burning, cutting, cultivating, or pasturing such areas are apt to be characterized by worn-out, shallow, or infertile soils and by a growth of grasses, weeds, and shrubs which offer severe competition to the small trees. Under these conditions even conifers may grow slowly at first, but their survival is usually greater and their yield of usable material higher in the same period than is true of hardwoods. Hardwoods, if planted at all, should be confined to the more moist and fertile sites.

Northern white pine [4] has been more generally planted than any other tree and is well adapted to a wide variety of sites. When

[4] For the botanical names of tree and shrub species mentioned in this bulletin, see p. 100.

used, however, it must be protected against the blister rust, a serious disease now prevalent throughout the Northeast, by the methods described later in the discussion of the white pine types. It is also subject, particularly in pure stands, to damage by the white pine weevil. Norway pine is another vigorous and valuable tree which deserves to be more widely used than at present, since it thrives even better under adverse conditions than the white pine and is less subject to attack by insects and disease. Scotch pine, a native of Europe, usually starts well on poor soils, but can not be highly recommended for general use because of its tendency to be of poor form and to suffer from snowbreak. Norway spruce (another European tree) and white spruce require somewhat better sites, but are nevertheless hardy and desirable trees, suitable for rather general use, particularly in the northern part of the region. Mixed plantations, as of white and Norway pine, or of pine and spruce, although not so far widely used, have the advantage of being less liable to complete destruction in case of attack by insects or disease.

In general, it is a safe rule to choose those species which occur naturally or which have been planted successfully on sites similar to those to be planted. Exotic species are of doubtful value, except on sites where their success has been demonstrated by actual plantations. It is also safe for those without previous experience in planting to seek advice from their State forester as to the best species or combinations of species to select out of the very wide variety that might be used.

Experience has shown that in the long run thrifty nursery stock is cheaper and gives better results than wild stock or the direct sowing of seed on the land to be reforested. The best age and size of stock to use depend on the species and on the character of the area to be planted. Two-year-old seedlings of pine may be satisfactory where there is little competition from grass, weeds, and brush, whereas 3 or even 4 year old transplants may be needed where such competition is likely to be severe. For spruce, 3 or 4 year old transplants are usually desirable. Conifer seedlings or transplants for field planting may well range from 4 to 6 inches in height and should preferably have vigorous bushy tops and a good bunch of fine roots. These can be handled more easily and cheaply than can larger plants. Hardwoods develop much more rapidly in the nursery and can best be planted as 1 or 2 year old seedlings.

Young trees for planting can be grown by the timberland owner in his own nursery or purchased from a State or commercial nursery. (Pl. 5, A.) State nurseries from which stock can be obtained for planting within the State are maintained by the forestry departments of Maine, New Hampshire, Vermont, Massachusetts, New York, New Jersey, and Pennsylvania, and by the Connecticut Agricultural Experiment Station. Names of reliable dealers can also be had from these sources.

ESTABLISHING THE PLANTATION

In the spring, as soon as possible after the frost is out of the ground, is generally considered the best season for field planting (*48*). Considerable success has, however, attended planting in

the fall after growth has ceased but before the ground freezes. In either event, moist soil at the time of planting is essential. Planting should also preferably be done on cool, foggy, or drizzly days, and the roots of the young trees, particularly of conifers, should not be allowed to dry out.

The trees are usually planted in rows with a spacing of 8 by 8 to 6 by 6 feet. This requires 680 to 1,200 trees to the acre. The wider spacing is used when it is desired to cover a considerable area at low cost, or when rapid growth is desired at the expense of quality. For most purposes a spacing of 6 by 6 feet, or a little more, will prove satisfactory. Spacings as close as 4 by 4 feet, or even 3 by 3 feet, may sometimes be desirable for special purposes, such as the growing of bean poles or Christmas trees or minimizing the damage by the white pine weevil, but they should not be used when the production of lumber is intended, unless subsequent thinning to prevent overcrowding is practicable.

Careful setting of the young trees to give them a good start is important. (Pl. 5, B.) Any heavy growth of sod or weeds should first be cleared off for a space of at least a foot square. A hole should then be dug deep enough and wide enough to accommodate the roots, and the better top soil should be kept separate from the poorer soil. The roots of the tree to be planted should be well spread out in the hole and the topsoil pulled in over them and packed down with the closed fist. Loose trash, grass, weeds, and moss should not be used, since they can not be packed tightly and are likely to result in the drying out of the roots and the consequent death of the plant. Enough additional soil should then be pulled in so that when it is well firmed it will fill the hole to the ground level. The tree itself should be set at about the same depth in the soil as it stood in the nursery. Finally, it should be surrounded by a shallow layer of loose soil to act as a mulch.

Where the soil is light and free from rocks, planting can often be done successfully by setting the trees in slits made with a spade, mattock, or grub hoe. The slits are made by driving the tool into the soil to the full depth of the blade and working the handle back and forth. The roots are then inserted in this V-shaped opening, and the soil is pressed around them with the foot or by again driving the spade into the soil about 4 inches away and forcing the soil over against them. The chief objection to this method is that the roots can not be so well spread out or the soil packed so firmly around them. It is therefore not so sure as planting in holes, but can be carried on about twice as rapidly.

Where cultivation is possible, the plants can advantageously be set out in plowed furrows. On such sites subsequent cultivation is also beneficial in reducing the competition of other vegetation.

COSTS AND YIELDS

The cost of planting stock varies widely. In Maine, New Hampshire, Vermont, Massachusetts, New York, New Jersey, and Pennsylvania stock is distributed to residents of the State at approximately the cost of production plus shipping charges. Prices run from a minimum of $2 a thousand for 2-year-old seedlings to $10 a thousand for 3-year transplants. The cost from commercial nurseries is usually somewhat higher.

On average sites one man can plant at least 500 trees in an 8-hour day. With labor at $4 per day, and with 1,000 trees to the acre, this would mean a cost of $8 per acre for the actual planting. Where planting is unusually difficult, or where closer spacing is used, the cost would naturally run somewhat higher, and somewhat less where planting is easier or spacing wider. Under ordinary conditions the total cost of stock and planting will vary from about $10 to $20 per acre, with an average of perhaps $15 per acre.

The yield will vary chiefly with the quality of the site, the species and spacing used, and the subsequent treatment given the plantation. Cultivation of the soil during the early years will increase growth, but on most of the areas where planting will be done cultivation is so difficult and expensive that the results will hardly justify the cost. Cutting back the brush is often profitable, where much is present and it threatens to choke out the planted trees. As the stands become older, cutting out the poorer trees will help the growth of the better and will often be immediately profitable where the material removed can be marketed. These operations will be discussed in more detail later in connection with specific forest types.

Comparatively few plantations in the region are yet old enough to indicate conclusively what yields can be expected when they reach merchantable size. In general, the yields should be at least as large as those from well-stocked natural stands on similar sites, for which the available figures are given later.

A study in 1921 (*15*) of 16 northern white pine plantations in Rhode Island, Massachusetts, and New Hampshire, comprising the bulk of all pine plantations in New England over 25 years old, showed yields ranging from 11,160 board feet per acre at 27 years of age to 44,440 board feet per acre at 63 years of age. These were all on abandoned farm lands, which were doubtless characteristic of such lands in need of reforestation. The spacing varied from 4 by 4 feet to 22 by 25 feet, but in 12 of the plantations spacings of 6 by 8, 8 by 8, 8 by 10, or 10 by 10 feet were used. The average spacing was therefore somewhat wider than is now common. Beyond the removal of dead and badly suppressed trees, only one of the plantations had been thinned. This thinning, in 1908, yielded 14,000 board feet of box boards and 40 cords of wood, with a net profit of $20 per acre.

Plotting the figures for these 16 plantations on cross-section paper and drawing a smooth curve through the points thus obtained gave the average yields indicated in Table 4. These yields are slightly lower from 40 years on than those of well-stocked natural stands on sites of average quality. They probably indicate the minimum that can reasonably be expected from successful plantations of white pine on abandoned farm lands, and somewhat more than can be expected on soils of poorer quality.

TABLE 4.—*Yields of northern white pine on 16 plantations in New England, 1921*

Age (years)	Yield	Average annual growth	Age (years)	Yield	Average annual growth	Age (years)	Yield	Average annual growth
	Board feet	*Board feet*		*Board feet*	*Board feet*		*Board feet*	*Board feet*
25	6,200	250	40	21,500	540	55	34,000	620
30	11,500	380	45	26,000	580	60	37,400	620
35	16,600	470	50	30,100	600	65	40,400	620

Yields from Norway pine plantations should run at least as high as for white pine (*36*). Scotch pine grows more rapidly at first but does not hold out so well. Both European larch and Japanese larch make extremely rapid growth in height in their early years, but natural thinning soon results in stands so open as to make it doubtful that these species can equal the pines in volume production.

Norway spruce and white spruce grow slowly at first, but more rapidly later, and maintain fairly dense stands. An exceptionally fine 44-year-old plantation of Norway spruce in Vermont in 1924 yielded 49.2 cords, or about 25,000 board feet, per acre. In northwestern Pennsylvania, a 42-year-old plantation of Norway spruce, with some Scotch pine and hardwoods, had in 1925 a total yield of 47.4 cords per acre. In general, spruce can be expected to yield somewhat less than pine in the same period in total cubic feet, or cords, and considerably less in board feet.

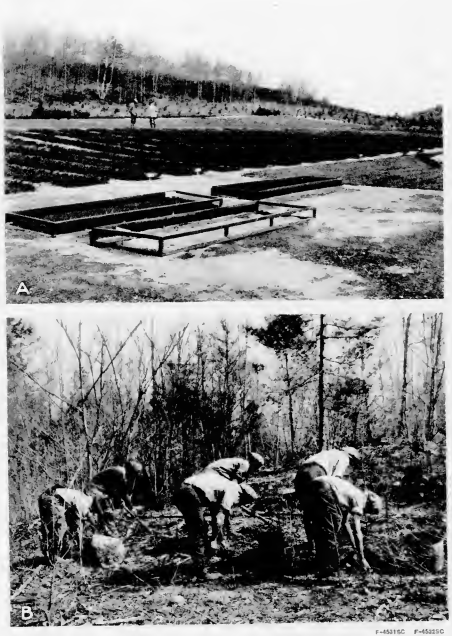
Average figures of the financial returns from plantations are difficult to give because of the many items which must be considered, such as the cost of planting, administration, protection, and taxes, in relation to the probable amount of material to be produced and its stumpage value. Specific cases indicate that northern white pine on soil of medium quality will usually return from 4 to 6 per cent compound interest on the total investment. Planting is therefore not only necessary to restore many areas to productivity, but except on very poor sites or in remote localities where stumpage values are apt to continue low, is likely to prove a profitable operation. In estimating returns, consideration should be given to the fact that many of the Northeastern States provide preferential taxation for plantations.

That the prospects of reasonable profit are sufficiently good is attested to by the fact that forest planting is markedly on the increase. Planting affords the only means of restoring many idle areas to productivity in a reasonable time, and can often be used to advantage to increase the productivity of existing stands, as will be indicated later.

SUMMARY OF MEASURES NECESSARY TO KEEP FOREST LAND PRODUCTIVE

FIRE CONTROL

Although large areas in the Northeast have been laid waste by fire and reduced in productivity by injudicious cutting, natural conditions are so favorable for tree growth that some kind of forest is reasonably sure to follow cutting if fires are kept out. The new



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PLANTING OPERATIONS ON THE EWING STATE FOREST IN MASSACHUSETTS

A, Nursery where forest trees are raised for planting on State lands and for distribution to private timberland owners; B, a crew setting out white pine transplants on a cut-over area in need of reforestation.

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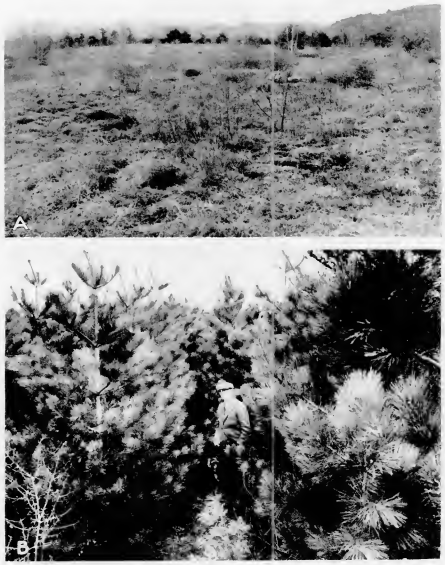

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ABANDONED PASTURES ARE HIGH-GRADE FOREST LAND

The Norway pine plantation shown in B is on light sandy soil and outcropping rock similar to the old field in A.

forest will often not be satisfactory from the standpoint of stocking or species represented, but will be sufficient to prevent denudation. Fire control is therefore nearly the only requirement that is absolutely necessary to keep most land already forested at least partially productive. Full production is quite a different matter, requiring adequate protection against animals, insects, and diseases, together with the proper silvicultural treatment of the forest.

The most essential features of adequate fire control are:

Centralization of control activities in an organization which is statewide in scope and under public control (preferably the State forestry department).

Division of the State into fire districts and subdistricts, with competent officials in charge of each.

Maintenance of lookout towers for the prompt detection of fires.

A suppression organization that can get a properly equipped crew of sufficient size to every fire at the earliest possible moment.

Fire crews instructed to keep close watch of every fire, even after it is under control, until it is completely out.

Penalties for carelessness with fire in any form.

Authority to put a stop to hunting or fishing, or to close the woods completely, during periods of exceptional danger.

Permits for burning brush or lighting camp fires during the fire season.

Use of spark arresters by railroad engines not burning oil, and by sawmills operating in the vicinity of forest land.

Disposal of slash along highways and main logging roads and in other unusually dangerous places.

Elimination of inflammable débris on railroad rights of way.

Patrol of railroad tracks during dry periods and in dangerous localities.

Reduction of carelessness by educational measures and strict enforcement of the law.

Cooperation of timberland owners, either individually or through associations, with the State organization, and such additional precautions on their part as may be necessary to safeguard their own lands.

The cost of these measures will probably vary from 2 to 10 cents per acre of forest land, depending on local conditions. Practically all of them are in effect in one or more of the Northeastern States, and many of them in all.

PLANTING

Planting is necessary to restore forest productivity on lands which have been so severely burned as to prevent natural reproduction, on occasional unburned cut-over areas which have not reproduced naturally, and on abandoned farm lands which are not reverting to forest (Pl. 6). Thrifty nursery stock of species adapted to the site and large enough to compete successfully with any other vegetation on the ground should be used. Protection against fire and pests should be assured before and after the plantation is established. Yields at least equal to those of well-stocked natural stands on similar sites may be expected from such plantations.

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PRODUCING FULL TIMBER CROPS

THE REAL FOREST PROBLEM

Merely keeping some kind of tree growth on forest lands is a step in the right direction, but only a step. The real forest problem in the Northeast is how to produce full timber crops on lands now partially idle. More specifically, it is one of building up large areas of run-down, often badly run-down forests. Even where fire has been kept out, cutting and subsequent neglect have rather generally resulted in a progressive deterioration which is evidenced by poorly stocked stands and increased representation of the less desirable species. To-day comparatively little forest land in the region is producing the yield of which it is capable.

This is a situation which can hardly be viewed with complacency by either the public or the individual timberland owner, particularly in view of the fact that conditions are so favorable to the practice of forestry. Stumpage values are high, ample markets are close at hand, and the more valuable trees respond readily to treatment. The estimates by the Forest Service given in Table 5 bring out clearly the differences in rate of growth which may be expected (1) under present conditions; (2) under "crude forestry," by which is meant fire control and, in some regions, such simple silvicultural measures as the leaving of seed trees when the timber is logged; and (3) under "intensive forestry," by which is meant the intensive management of forests as crops.

TABLE 5.—*Estimated annual rate of growth per acre in different northeastern forests under different degrees of management*

Character of forest	Under present conditions	Under crude forestry	Under intensive forestry	
			Average	Maximum
	Cubic feet	*Cubic feet*	*Cubic feet*	*Cubic feet*
Spruce and fir	20	25	45	80
Birch, beech, and maple	25	30	60	120
White pine	40	45	100	170
Oak and mixed hardwoods	25	30	60	120
Oak and pine	22	27	65	105

Since comprehensive data are not available regarding present and probable future growth under the wide variety of forest conditions in the Northeast, these estimates are at best approximations. They are believed, however, to be conservative with respect to the increased growth possible under intensive forestry. If so, it is evident that efficient management will pay as well in timber growing as in agriculture, manufacturing, or any other enterprise. In fact, intensive forestry may be the only means of converting a run-down, neglected forest into a profitable investment. European experience has proved that within reasonable limits increased expenditures for forest management mean increased net returns, and there is no reason why this should not be equally true in the United States.

With more than 90 per cent of the forest land in the Northeast in private ownership, increased production must result chiefly from the efforts of individual timberland owners. Unlike fire control, which must be handled by a single organization that is state-wide in scope and authority, intensive forestry on areas under different ownership does not lend itself so readily to centralization.

This does not mean that public participation in timber growing should be limited to fire control. The interest of the entire community in the proper use of forest land and the production of adequate timber supplies is sufficient to justify State activity in such other directions as the distribution of planting stock, the conduct of research, and the dissemination of information as to the best methods of forest protection, production, and utilization, the acquisition and management of State forests, and the placing of forest taxation on an equitable basis. Legislation aimed at maintaining forest production through a certain degree of State control over private cuttings may even be desirable.

It is hardly conceivable, however, that these measures, all of which are now in force in one part or another of the Northeast, would by themselves result in maximum production. Short of actually taking over the management of all forest lands, the State can go only so far in the way of help or coercion. Beyond that point the production of full timber crops is in the hands of the individual owner.

WHAT INTENSIVE FORESTRY INVOLVES

Adequate fire control along the lines discussed is obviously the first essential for intensive forest management. It is worse than useless to spend time and money in building up a forest which is likely to be burned over at any time. The owner who is really interested in getting the most out of his land will, therefore, supplement State activities by taking such additional precautions as are necessary to safeguard the forest property effectively from fire. These may include more complete disposal of slash than the law requires, special patrol, maintenance of an adequate supply of fire-fighting equipment, and the liberal use of fire-warning signs and posters.

Next in importance to fire control comes protection from other destructive agencies, such as insects and diseases, and then silviculture, or the art of producing and tending the forest itself. While insects and diseases seldom cause devastation comparable to that resulting from fire, they may, if uncontrolled, virtually prevent the growing of certain trees. This is true, for example, of the chestnut blight and the white pine blister rust. Moreover, they are responsible for a steady drain on the forest which, with the system of fire control now in effect, probably results in a larger total loss than that due to fire.

Silviculture includes methods of establishing the forest and of caring for it so as to obtain the maximum yield of desirable species. It goes hand in hand with protection from insects and diseases, of which it is often the most effective means. Detailed suggestions for the treatment of different forest types will be given later.

The next step beyond keeping the land productive through protective and silvicultural measures is to plan cutting operations so as to obtain a regular income. Since the forest is a crop which requires many years to reach maturity, this necessitates (1) maintaining a constant growing stock, or forest capital, and (2) limiting the amount

of timber cut during any given year or period of years to approximately the amount grown, or the income produced by this capital, during that period. When more than this amount is cut, the difference represents the extent to which the forest capital, and consequently its income-producing power, have been depleted.

The principle involved can best be illustrated by a hypothetical example. Imagine a 2,000-acre tract of white pine which is growing at the average annual rate of 750 board feet per acre, with a yield of 37,500 board feet in 50 years. Imagine further that this tract is divided into 50 units of 40 acres each, with stands ranging regularly in age from 1 to 50 years. Each unit will then contain 1,500,000 board feet when it is 50 years of age. This amount can, therefore, be removed year after year indefinitely, provided cutting on each unit is followed by satisfactory reproduction, since in 50 years the original stand will have been replaced by a new one of equal volume. In this example the growing stock, or capital, is 37,500,000 board feet and the annual growth, or income, 1,500,000 board feet.

Such ideal conditions are, of course, never found in nature. On any area of considerable size, sites vary in quality; stands are irregular in age, composition, and rate of growth; and fire, insects, diseases, wind, drought, and other factors upset the best-laid plans. Nevertheless, it is possible to determine the growing capacity of even the most irregular forest much more accurately than is now customary, and to regulate its utilization accordingly (*9*). The methods by which this is done can not be considered in this bulletin, but attention is called to the importance of sustained yield in placing the management of a forest property on a thoroughly businesslike and effective basis.

The outstanding advantage of maintaining an ample growing stock is that it permits a regular income. The most common objection to forestry is that taxes, protection, and other costs must be carried over many years as compound interest before the forest can be harvested and a return realized. This is true only when forestry starts with bare land or young stands. Compound interest holds no terrors for the owner where property consists partly of merchantable timber and partly of young growth, and who handles it so as to maintain a balance between growth and cut. Current expenditures can then be met from current receipts as in any other business; and compound interest can be as completely forgotten by the timberland owner as it is by the farmer or the merchant.

Finally, intensive forestry requires a definite and clear-cut plan of management. The owner should know where his property lies, of what it consists, how it is to be protected, what methods of cutting and subsequent treatments are to be used in different types, how much timber can be cut each year, and where such cutting should be located. For large areas these facts and plans should be recorded in permanent form. They should also be revised and brought up to date from time to time as changing conditions make this necessary. For small areas, such as farm wood lots, a written plan is less necessary; nor is so strict an application of the principle of sustained yield possible. Every owner will, however, find it to his advantage to know his forest thoroughly and to plan on handling it so that it will yield as large and as regular a return as possible.

SPRUCE AND NORTHERN HARDWOODS REGION

The spruce and northern hardwoods region is characterized by an abundance of spruce, balsam fir, sugar maple, yellow birch, paper birch, and beech. Other common species are northern white cedar, tamarack, eastern hemlock, basswood, white ash, red maple, and the aspens. Northern white pine now occurs only scatteringly, although it is largely from this region that the famous white pine masts of colonial days were obtained. The principal forest types are spruce-swamp, spruce-flat, spruce-hardwoods, spruce-slope, old-field spruce, northern hardwoods, and birch-aspen. The northern white cedar type occurs fairly commonly in swamps in many parts of the region, but hardly occupies sufficient total area to require discussion here.

The region occupies all of northern and central Maine, northern New Hampshire and Vermont, and the Adirondack Plateau in New York. It extends south through the Green Mountains to the Berkshires in western Massachusetts, and reappears in the Catskills and in northeastern Pennsylvania. It is confined for the most part to the more remote and less thickly settled sections with poorly developed transportation facilities, as in northwestern Maine, which probably affords as good an example of real wilderness as is to be found anywhere in the country.

SPRUCE TYPES

The five spruce types—spruce-swamp, spruce-flat, spruce-hardwoods, spruce-slope, and old-field spruce—have so much in common that they can best be considered together. They are found only in the spruce and northern hardwoods region, where they furnish the bulk of the pulpwood supply. The spruce-flat, spruce-hardwoods, and spruce-slope types easily stand first in importance both commercially and geographically. The spruce-swamp and old-field spruce types cover relatively small areas, but the old-field spruce is of considerable importance locally because of its accessibility and usually large yields.

The spruce-swamp type occupies low, poorly drained sites with high water table and impervious soil of peaty character. Black spruce is the predominating species. Red spruce, balsam fir, tamarack, and northern white cedar are also common, with a sprinkling of black ash, red maple, and paper birch. Growth is very slow, and the mature trees are of small size.

The spruce-flat type occupies flat sites at low elevations where the drainage is better than in the swamps but poorer than on the slopes. Red spruce and balsam fir are the principal species and often form 90 per cent of the stand. Paper birch is sometimes common, particularly on burned areas, and other hardwoods usually occur scatteringly.

The spruce-hardwoods type occupies the well-drained slopes at medium elevations just above the spruce-flat type. Red spruce is the most abundant single species, with balsam fir frequently a close second. White spruce is common in parts of Maine and New Hampshire, but rare elsewhere. Yellow birch, paper birch, sugar maple, red maple, and beech, in widely varying proportions, often make up 50 per cent of the stand. Eastern hemlock and northern white

pine are also common associates. In spite of the great range in composition in different stands, the type is readily recognized by the abundance of spruce in mixture with hardwoods. Except possibly on old fields, spruce makes its most rapid growth and is of the best quality in this type. (Pl. 7.)

The spruce-slope type occupies steep, thin-soiled slopes at the upper elevations. Red spruce predominates, and often forms as much as 90 per cent of the stand. Balsam fir is locally abundant. Paper birch is common, but other hardwoods are scarce. Growth is slower than in the spruce-hardwoods type, but the stand is sometimes heavy. Toward timber line the trees become short bodied, small, and scrubby.

The old-field spruce type occupies land at one time cleared for agriculture, mostly for pasture, and is confined chiefly to northern New England. Pure stands of red spruce are most common. White spruce and balsam fir frequently occur in mixture with it, however, and pure stands of white spruce are not uncommon in Maine and New Hampshire. Other species occur only scatteringly. Soil conditions are usually good, with the frequent result that growth is rapid and yields are heavy.

The original spruce forests, except where they followed fire or windfall, were typically uneven aged. This condition was not radically changed by the early cuttings, which took out only the larger trees down to a breast-high diameter of 12 to 14 inches. Subsequent cuttings, however, have been increasingly heavy, until to-day a virtual clear cutting is the rule in pulpwood operations. As a result, future stands, not only in the old-field type but in other types, are likely to be increasingly even aged.

NATURAL REPRODUCTION [5]

Most of the species in the spruce types are so tolerant of shade that, except in the densest stands, a good "advance growth" of young seedlings and saplings is usually present. These young trees come in gradually, and the most tolerant, such as spruce, balsam fir, and maple, are able to persist for many decades in a suppressed but healthy condition under a fairly heavy overhead cover. Thus, spruce seedlings in a typical spruce-hardwoods stand usually average only about 3 feet in height at 30 years and 4.5 feet at 40 years. They are, however, able to recover readily from suppression, and a prompt and marked increase in growth usually follows the removal of the larger trees.

Studies of reproduction in the spruce-flat, spruce-hardwoods, and spruce-slope types in northern New England and New York show clearly (Table 6) that ample material for the production of well-stocked stands is ordinarily found on areas that have been heavily cut for pulpwood. Most of the spruce and balsam fir were on the ground at the time of the cutting, but many of the hardwoods came in later. The general failure of spruce and balsam fir to reproduce themselves naturally after cutting on areas where they were originally abundant is a striking and important fact.

[5] Most of the material in this section has been taken from a very detailed report by M. Westveld, of the Northeastern Forest Experiment Station, entitled "Reproduction on Pulpwood Lands and Suggestions for Their Management." Grateful acknowledgment is made to Mr. Westveld for permission to use the facts brought out in this manuscript prior to its publication.

TABLE 6.—*Number of trees per acre on cut-over lands in the spruce types in the Northeast*

Type	Spruce and balsam fir	Other species [1]	All trees
Spruce-flat [2]	3,015	1,154	4,169
Spruce-hardwoods [3]	1,689	3,176	4,865
Spruce-slope [4]	6,251	4,949	11,200

[1] Chiefly yellow birch, sugar maple, aspen, striped maple, mountain maple, and pin (fire) cherry.
[2] Data are from 245 plots from 2 to 40 years after cutting.
[3] Data are from 152 plots from 5 to 40 years after cutting.
[4] Data are from 16 plots from 3 to 15 years after cutting.

This failure is probably due in part at least to unfavorable seedbed conditions and to heavy early mortality. In uncut stands the thick layer of partially decomposed litter usually present is sufficiently moist to permit the ready establishment of spruce and balsam fir reproduction. After cutting, however, this litter dries out rapidly, with the result that these species are able to establish themselves only on such mineral soil as has been exposed by logging.

The relative abundance of spruce and balsam fir in comparison with hardwoods and other trees in the original stand and at various intervals after cutting is shown in Figure 5. Trees 1 inch or more in diameter at breast height are included in the original stand, and trees of all sizes in the cut-over stands. In general, the number of spruce and balsam fir present during the first few years after cutting is roughly proportional to their volume in the original stand and decreases steadily as the volume of the hardwoods increases. It is not unusual, however, to find considerable numbers of coniferous seedlings even in stands having a high percentage of hardwoods.

The most striking facts brought out by the comparison in Figure 5 are the ability of spruce and balsam fir to hold their own in the spruce-flat type, where the poorly drained soils are unfavorable to the hardwoods, and the marked encroachment of hardwoods and others in the spruce-hardwoods type and the spruce-slope type. This encroachment is probably permanent in the spruce-hardwoods type. Favorable soil conditions, abundance of seed, ability to come in after cutting, and rapid early growth all tend to give hardwoods the advantage and to enable them to crowd out the spruce and balsam fir. In the spruce-slope type all of the plots measured were on areas which have been cut so recently as to leave the final result uncertain. Conditions there are not so favorable for the hardwoods, however, and the spruce and balsam fir, whose persistence more than compensates for their slow start, will probably regain in time their dominant position.

When the relative abundance of the more valuable spruce is compared with that of the less valuable balsam fir, as in Figure 6, a strong tendency is evident for balsam fir to replace spruce in the spruce-flat type. The representation of spruce decreased from 56 per cent in the original stand to an average of 34 per cent in 5 to 40 year old cuttings, while that of balsam fir increased from 44 to 66 per cent. This was due primarily to the ability of the balsam to grow more rapidly after removal of the overhead cover. Its greater

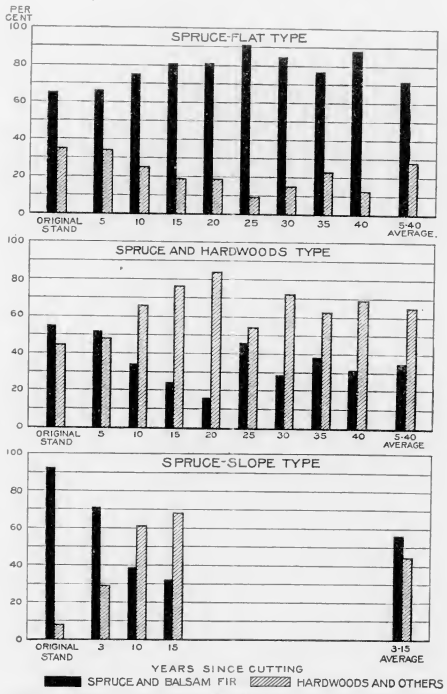
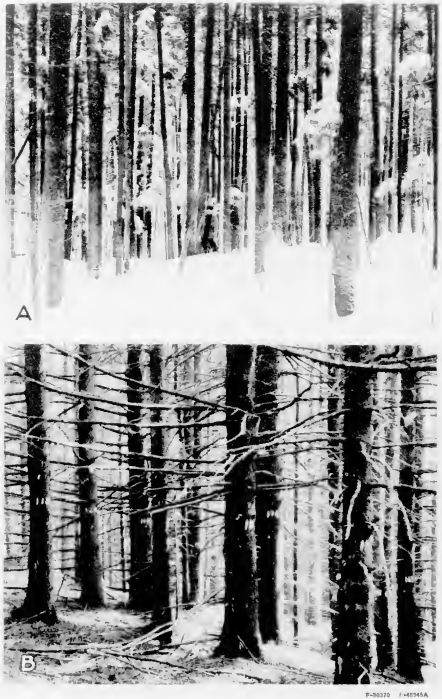
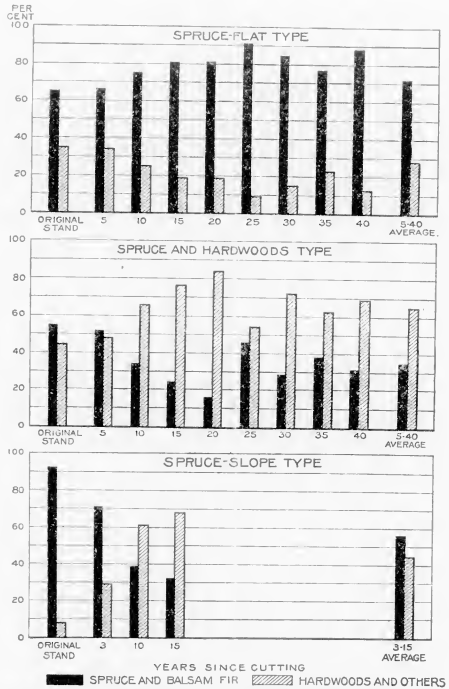


FIGURE 5.—Relative numbers of spruce and balsam fir and of hardwoods and other trees present in the original stand and at various intervals after cutting



DENSE AND OPEN SPRUCE STANDS IN NEW HAMPSHIRE

A, A dense stand of merchantable spruce on the summit of a ridge. Clear cutting in such a situation as this is the only method of logging not likely to result in heavy windfall. B, an example of the old-field spruce type. Note the large number of dead branches retained by the trees in this young open-grown stand as compared with the older, denser stand shown in A.



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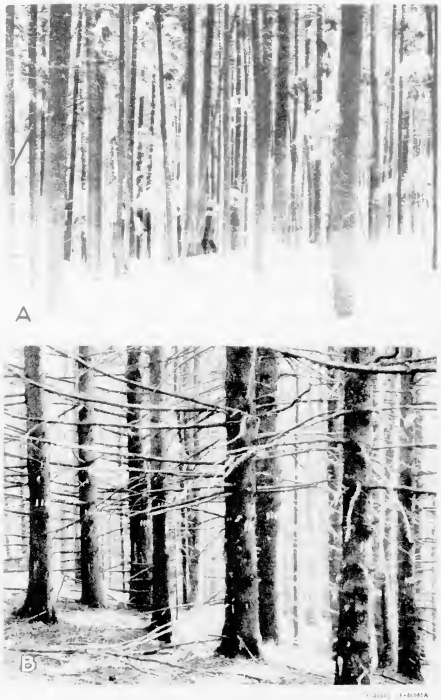

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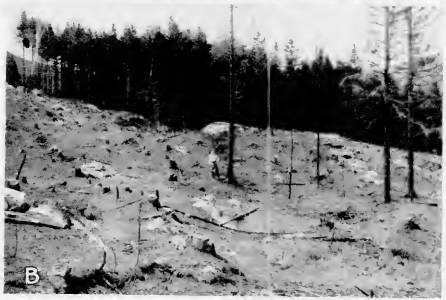

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THE IMPORTANCE OF ADVANCE REPRODUCTION IN SPRUCE CUTTINGS

Note the abundance and vigorous growth of the spruce and balsam fir seedlings (A) after clear cutting in a stand of spruce with ample advance coniferous reproduction in contrast with the results in a stand of spruce without advance reproduction (B). Hardwoods may creep in gradually on the latter areas, but reproduction of spruce and balsam fir is unlikely. Both views are in Grafton County, N. H.

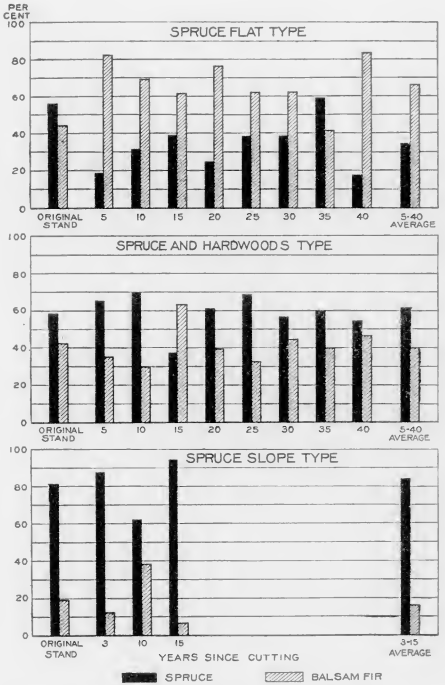
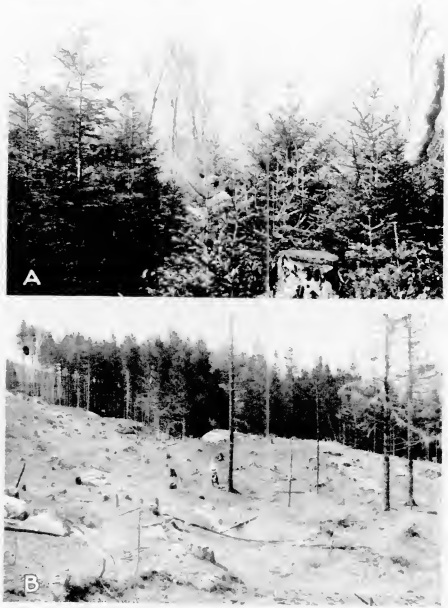


FIGURE 6.—Relative numbers of spruce and of balsam fir present in the original stand and at different lengths of time following cutting

Delmont Hill Inc. U. S. Dept. of Agriculture PLATE 6



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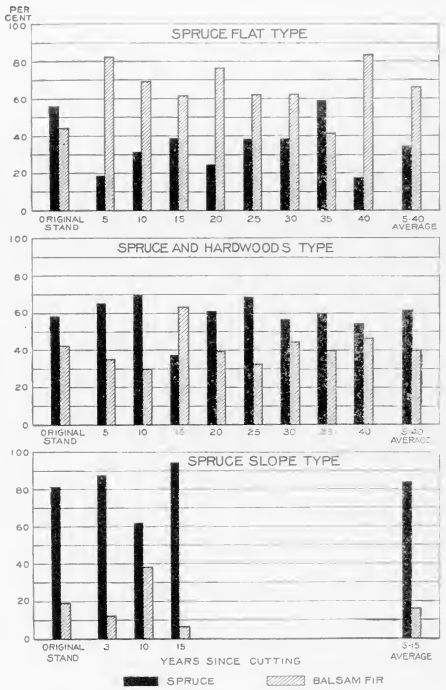


FIGURE 6.—Relative numbers of spruce and of balsam fir present in the original stand and at different lengths of time following cutting

aggressiveness leaves little doubt that balsam fir will predominate at the time of the next cutting in spite of the greater persistence and longer life of the spruce.

In the spruce-hardwood type, on the other hand, the more tolerant and persistent spruce is better able to hold its own in competition with the hardwoods. Although both spruce and balsam fir tend to be crowded out after cutting in this type, there is little danger that balsam fir will encroach to any marked degree on spruce. Spruce also maintains its much greater abundance in the spruce-slope type, where the thinner, drier soils are less favorable to the balsam fir.

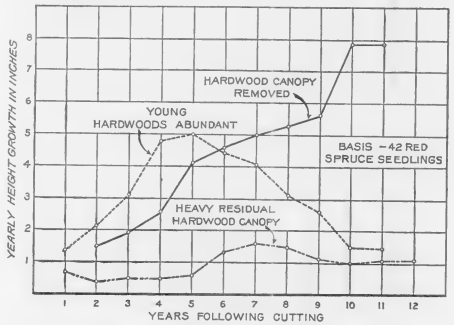


FIGURE 7.—Yearly height growth of spruce seedlings after cutting in three different conditions of hardwood competition

The growth of spruce and balsam-fir seedlings after cutting varies both with the degree of suppression and with their height at time of release. In general, the best response is from seedlings between 1 and 5 feet in height. Spruce seedlings of all sizes on cut-over areas in the spruce-hardwoods type, where the overhead cover had been entirely removed, attained an average height of 77 inches in 12 years as against 20 inches in the same time under a dense cover. Balsam fir, responding more quickly and growing more rapidly after liberation, does better than this. Both species when in mixture with hardwoods at first increase in rate of height growth and then decrease rapidly as the competition of the hardwoods makes itself felt. (Fig. 7.)

About 20 per cent of the advance growth of all species is destroyed, much of it unnecessarily, during logging operations. (Fig. 8.) The heaviest loss with spruce and balsam fir is in the seedlings which are from 1 to 5 feet in height and which because of their vigor and rapid growth form the main reliance for the next crop of pulpwood.

METHODS OF CUTTING

Whenever advanced growth is abundant in the spruce-flat type, as it usually is, clear cutting of all merchantable trees is advisable. (Pl. 8.) This will permit the maximum development of the young trees already on the ground and should result in a well-stocked new stand Often the new stand will be so dense as to retard its growth. Whether or not this is the case can be determined either from appearances or by boring into or cutting down a few trees and examining their annual rings. If in the young trees these rings are decreasing steadily in width it is pretty sure evidence that the stand is too dense and consequently is in need of thinning. By removing the smaller, poorly formed, and less thrifty trees, the crowns of the larger, more vigorous individuals can be freed and thereby given

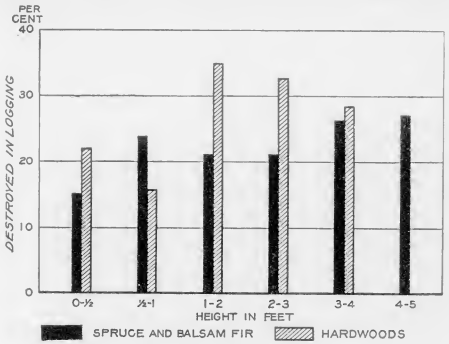


FIGURE 8.—Destruction of advance growth during logging

ample opportunity for development. Such thinnings are worth while when the material removed can be marketed with little or no loss; but it is impossible to state without further investigation how large a net outlay in thinning operations would be justified solely by the resultant increase in final returns from the timber crop.

Where advance growth is scanty, only a third to a half of the crown canopy should be removed. This will stimulate and encourage reproduction, and after the new reproduction is well established, the remainder of the stand can be cut clear. The chief objection to partial cutting aside from extra cost, which may perhaps run as high as $0.50 per cord, is the danger from windfall. Both spruce and balsam fir are such shallow-rooted species that heavy loss from this cause often follows cutting in stands with exceptionally tall trees, on areas especially exposed to the wind, or on sites with unusually shal-

low or moist soil. Where these conditions exist, the first cutting should remove even less than a third of the stand.

In the spruce-hardwoods type, the advance growth of spruce and balsam fir is less generally satisfactory than in the spruce-flat type. Where advance growth is plentiful, clear cutting of both conifers and hardwoods to the lowest merchantable diameter will give it the best opportunity for development. However, where yellow birch is the prevailing hardwood in the stand, the spruce and balsam fir seedlings should have an average height of about 2 feet to enable them to hold their own, and they should be at least 4 feet high where sugar maple or beech predominates. A good illustration of the competition sometimes met by the conifers is afforded by a stand on the White Mountain National Forest, which contains 13,000 sugar maple seedlings less than 5 feet high as against 900 red spruce and balsam fir. Eighty per cent of the spruce and fir are less than one-half foot in height. Under these conditions the spruce and balsam fir, although present in sufficient numbers to form a satisfactory basis for a new stand, are almost certain to be choked out by the much more abundant maple with its characteristically heavy foliage and spreading crown.

The development of the conifers after clear cutting can be greatly aided by cutting back the competing hardwoods. This is particularly necessary with maple and beech, and where these are abundant it may be the only means of retaining any considerable representation of conifers. When the spruce and balsam fir are from 3 to 5 feet in height, the hardwoods should be lopped back at a convenient height with a machete, brush hook, or hand ax wherever they are overtopping or crowding the conifers. Although not enough work of this sort has been done to prove definitely how much it will increase the growth of the conifers, relative development on areas where hardwood competition is severe and where it is naturally lacking indicates that the average growth of the conifers will increase at least 100 per cent and probably more. Experiments by a pulp company in New Hampshire indicate an average cost of about $2 an acre.

Heavy cutting of the merchantable hardwoods, or even any cutting of them at all, is often impracticable because of the impossibility of profitable marketing. When this is the case, the advance growth (and subsequent reproduction) of spruce and balsam fir will be seriously held back by the overhead shade of the hardwoods and their heavy draft on soil moisture. This competition can be reduced by girdling and killing some of the hardwoods. The girdling may be done by removing a strip of bark or cutting a shallow notch entirely around the tree. The notch, which appears to be the more effective in killing the tree, may be made most readily by two downward strokes of the ax, the second above the first.

Experiments by a pulp company in New York show a girdling cost of about 1.8 cents a tree, or $1.30 an acre, with a range from $1 to $1.75 an acre (*10, 11*). Girdling an average of 72 trees per acre released about 400 spruce and balsam fir seedlings at a cost of 0.3 cent for each tree released. The forester in charge of the work estimates that without such release only a third of these trees would have survived and that the survivors would have taken twice as long to

reach merchantable size. In a somewhat similar experiment in Maine girdling an average of 62 hardwoods an acre was estimated to cost $1.50 an acre, with resultant benefit to two spruce and balsam fir trees 5 feet or more in height for each tree girdled (*8*).

Girdling should, of course, be limited strictly to hardwoods which are actually interfering with the development of good coniferous reproduction and which, because of poor quality or inaccessibility, are practically certain to have no commercial value in the near future. The removal of "wolf" trees with widely spreading crowns is particularly important.

Where spruce and balsam fir reproduction in the spruce-hardwoods type is inadequate, as it often is in stands which have been repeatedly culled for these species, it will be difficult to obtain any considerable amount of conifers at reasonable expense by any method of cutting. Removing all merchantable hardwoods and leaving the conifers offers the best possibility. With hardwood seedlings already in possession of the ground, however, even this is of doubtful efficacy. It also has the disadvantage of exposing the remaining conifers to windfall, which, although not so serious as in the spruce-flat type, is still a factor to be taken into consideration. Stands of this sort can most advantageously be handled to favor the best hardwoods in much the same way as is suggested for the northern-hardwoods type.

In the spruce-slope type, reproduction of spruce and balsam fir is nearly always adequate. Clear cutting is therefore satisfactory and, indeed, almost compulsory because of the extreme danger from windfall on the thin-soiled exposed sites occupied by this type. Partial cutting is almost certain to result in heavy loss. The only real alternative to clear cutting is, therefore, to leave the stand intact as a protection forest. This may be advisable in the rather rare instances where reproduction is lacking. Also, and more commonly, this course may be advisable where the forest cover is of great importance in preventing erosion and regulating stream flow. Fire constitutes an exceptionally high hazard after cutting in this type, slash fires on these slopes being frequently so severe as to destroy not only the stand but even the soil itself.

In the spruce-swamp type, reproduction is usually abundant and the danger from windfall great. Clear cutting is, therefore, satisfactory and the only safe method for general use.

Clear cutting is also advisable in the old-field spruce type wherever there is an abundance of advance growth. This is ordinarily the case except in unusually dense stands, which can advantageously be removed in two cuttings. In such stands the first cutting should remove from a third to a half of the crown canopy, as recommended for the spruce-flat type. The remainder of the stand can then be cut after reproduction is well established. The old-field spruce type usually occurs on fairly deep, well-drained soils where the danger of windfall after partial cutting is not great.

Care should be taken in logging all of the spruce types to do as little injury as possible to the advance growth of spruce and balsam fir. Hardwoods, on the other hand, may be cut back freely if it is desired to favor the softwoods. Grazing of cut-over lands will also help to keep back the hardwoods and thus to give the spruce and

balsam fir the advantage. It is, in fact, highly probable that the practically pure softwood stands so frequently found in the old-field spruce type are due in large part to grazing.

SLASH DISPOSAL

When any considerable volume of timber is removed, the slash left after logging is likely to be sufficiently dense over a large part of the area to interfere seriously with reproduction. Figure 9 shows the percentage of the area covered by slash after cuttings of different severity on three experimental plots in the spruce and hardwoods type in New Hampshire. Approximately 2 per cent of each

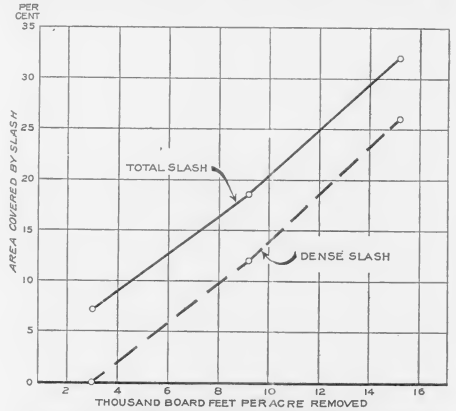


FIGURE 9.—Relation between volume cut per acre and percentage of area covered by slash in the spruce-hardwoods type

plot was covered by slash for each thousand board feet of timber removed, and the amount of dense slash varied from 0 to 81 per cent of the total. In an adjacent plot from which 8,750 board feet were removed 39 per cent of the area was covered by slash, but only 46 per cent of this, or 18 per cent of the whole, was classified as dense.

Both the total area covered by slash and the area covered by dense slash will vary not only with the amount of material cut but with the character of the stand and the way in which the slash is handled. Spruce and balsam fir, with their much smaller crowns and much closer utilization, produce considerably less slash than hardwoods. On the other hand, the conifer slash is piled much more

closely. Consequently, for equal volumes of timber removed, conifers produce less total slash than hardwoods, but a considerably larger percentage of dense slash. Both facts are brought out in the figures in Table 7, which were derived from one of the plots mentioned in the preceding paragraph.

TABLE 7.—*Area covered with slash and character of slash after cutting on an experimental plot in the spruce-hardwoods type in New Hampshire*

Species	Volume per acre removed	Area covered with slash	Character of slash		
			Dense	Medium	Light
	Board feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Conifers	4,690	17	62	23	15
Hardwoods	4,060	22	36	33	31

Dense slash is formed by the common practice of throwing the branches together in piles or windrows, often several feet deep. This practice is regarded as essential to clear the ground for logging unless the slash is got out of the way by burning; but it is none the less detrimental to the production of full crops of timber, since a really dense pile or windrow is likely to prevent any growth on the area beneath it for as much as 10 to 20 years. The loss of spruce and balsam fir seedlings in the course of two years under slash of different densities is shown in Figure 10. If the 12 per cent which died where there was no slash represents the normal mortality of seedlings up to 4 feet in height on the plots in question, then the loss due to slash during the first two years after cutting averaged 13.5 per cent under light and medium slash and amounted to 34 per cent under dense slash. There is little doubt that under the dense slash the loss will continue until it is practically complete.

This waste of good growing space can be avoided by burning the conifer slash currently during late fall or winter logging, when there is little danger of starting a forest fire. The slash should be thrown on small burning piles as the logging proceeds. This method avoids the greater fire risk, the larger area covered by slash piles, and the higher costs, which are involved when the slash is piled at the time of logging but left for burning later. Delayed burning may, however, be the only resort during spring or summer logging when the forest floor is so dry as to render any burning dangerous. In that case, the piles should be not more than 6 feet high or 8 feet in diameter, and should be placed where their subsequent burning will result in as little damage as possible to the adjacent reproduction and larger trees. The burning can be done in the late fall or early winter, when heavy rains or snows have made this safe.

Burning as the logging proceeds will, of course, kill all tree growth on the spots actually covered by the piles; but since relatively few piles are needed, these spots need not exceed 1 per cent of the total area. The cost will probably vary from $1 to $1.50 for each thousand board feet of conifer timber cut. The method is now in general use only on the White Mountain National Forest. Nevertheless, its advantages in increasing the space available for

forest production, in decreasing the fire hazard, and possibly in reducing the danger from insects and disease, commend its adoption wherever logging will result in covering any considerable part of the area with dense slash.

Burning hardwood slash is more difficult and less necessary. It does not form such dense piles as the conifers, and in the spruce types seldom covers a large percentage of the area so completely as to interfere seriously with the establishment of a new stand. Although its removal would be beneficial in the occasional instances where such interference does exist, burning would probably cost more than it is worth.

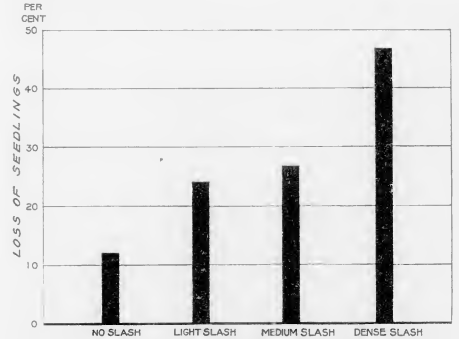


FIGURE 10.—Loss of spruce and balsam fir seedlings under slash of different densities, 1923–1925

PROTECTION FROM INSECTS

Both spruce and balsam fir are subject to serious injury from defoliation by larvæ of the spruce bud worm (*Cacoecia fumiferana*). This is a native insect which at more or less irregular intervals has caused tremendous loss. In Maine, for example, during the epidemic from 1910 to 1920 it destroyed two-fifths of the merchantable stand of spruce and balsam fir (*35*).

Outbreaks almost invariably start where an abundant supply of balsam fir, the favorite food plant of the bud worm, enables the insects to propagate in sufficient numbers to attack also the spruce. It is therefore important to check so far as practicable the tendency of this species, particularly in the spruce-flat type, to increase its representation at the expense of the spruce. This can be done to some extent by removing as much balsam fir as possible when partial cuttings are made in mature stands or thinnings in young stands. Early utilization of stands with a large percentage of balsam fir will also help, since it is the older trees with crowns well exposed to the sun which are most severely attacked.

Aside from reducing the proportion of balsam fir, the only hope of preventing bud-worm epidemics seems to lie in cutting out infestations the moment they appear. By training foresters and woodsmen to recognize bud-worm injury in its early stages and by keeping a sharp lookout for its presence, it should be possible to locate places where the bud worm is increasing abnormally before the infestation has reached serious proportions. The infestation in these places can then be checked either by putting in a pulpwood operation or, where this is not possible, simply by felling or girdling the affected trees. This will dry out the foliage sufficiently so that the bud worms will die. Unless infestations should spring up simultaneously over a very wide area, it should be possible in this way to hold the insect in check and to prevent the recurrence of any such destructive epidemic as the last one in Maine.

The eastern spruce beetle (*Dendroctonus piceaperda*) is another insect which in times past has caused heavy damage. During recent years, however, losses from it do not appear to have been serious, and its principal activity has ordinarily been in trees already weakened by the bud worm or some other agency. The damage is done by the larvæ, which girdle the trees by working in the inner bark. The insect may be controlled by cutting out the affected trees and putting them in water.

YIELDS [6]

The Northeastern Forest Experiment Station has recently measured some 400 sample plots and obtained the yields from fully-stocked, even-aged stands of red spruce as shown in Table 8 for the ages indicated.

The three sites represent good, average, and poor growing conditions, and do not include either the very best or the very worst. More specifically, good sites are taken as those on which the average dominant and codominant trees (i. e., the taller trees in the stand) reach a height of 60 feet in 65 years; average sites are indicated by a height of 50 feet at the same age, and poor sites by a height of 40 feet. Although the plots measured were largely in the old-field spruce type, the yields in other types should average approximately the same if the same criterion of site is used.

TABLE 8.—*Yields per acre of fully stocked, even-aged stands of second-growth red spruce in the Northeast; basis, 400 plots*

Age (years)	Good site		Average site		Poor site	
	Peeled pulpwood volume	Saw-log volume	Peeled pulpwood volume	Saw-log volume	Peeled pulpwood volume	Saw-log volume
	Cords	*Board feet*	*Cords*	*Board feet*	*Cords*	*Board feet*
40	17.4	2,200	11.7	1,200	6.3	0
50	39.7	9,900	29.1	6,200	17.6	2,800
60	58.4	20,800	44.2	13,900	29.0	5,800
70	69.7	31,800	54.2	20,300	36.5	8,800
80	76.6	38,900	60.0	24,800	41.3	10,800
90	80.5	42,800	63.2	27,400	43.8	11,900
100	82.8	45,100	65.2	28,800	45.4	12,600

[6] The material in this section is taken from a very detailed report by W. H. Meyer, now at the Pacific Northwest Forest Experiment Station (*32*). Grateful acknowledgment is made to Mr. Meyer for permission to use his material in this connection.

The cord volumes shown were obtained by converting into cords the cubic-foot contents of all trees with a breast-high diameter of 4 inches or more, from a 1-foot stump to a top diameter of 3 inches inside bark, exclusive of butt swell, on the basis of 95 cubic feet of solid wood to a stacked cord (peeled) of 128 cubic feet. The total volume of single trees with bark averages about 12 per cent higher than the same wood peeled. Since unpeeled bolts fit less closely than peeled an overrun of at least 15 per cent should probably be allowed in determining the solid contents of stacked cords of unpeeled wood. The board-foot volumes were obtained by scaling all trees with a breast-high diameter of 7 inches or more, from a 1-foot stump to a top diameter of 5 inches inside bark, in 16.3-foot logs, by the

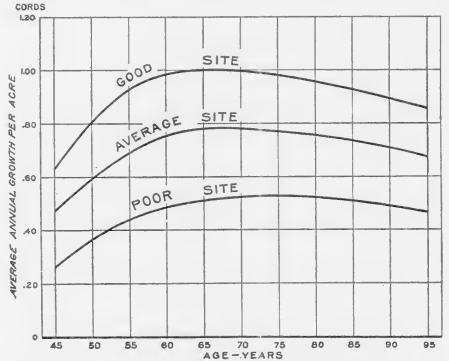


FIGURE 11.—Mean annual growth of fully stocked stands of second-growth red spruce in cords per acre

international rule with ⅛-inch saw kerf and with no allowance for cull.

Total age was determined by getting the age at breastheight and adding 15 years to allow for the period necessary to reach this height. In applying the figures given, the total age of the stand in question should be determined in the same manner, or by adding 7 years to the age as indicated on a 1-foot stump. Theoretically this period should not be the same for all sites, but a number of measurements of thrifty seedlings that had ample room for growth failed to show any consistent difference in this respect. It is evident that the influence on seedling development of the broad site classes recognized in the preparation of yield tables is somewhat obscured by local variations in soil conditions and competing vegetation,

which may be of minor importance to older trees but are of major importance to the young seedlings.

The mean annual growth at different ages is shown in cords of peeled pulpwood in Figure 11 and in board feet of saw-log material in Figure 12. For average sites pulpwood reaches its maximum at 65 years, saw timber at 82 years. To produce the greatest amount of high-quality lumber, however, would undoubtedly require considerably longer than 82 years, since natural pruning of spruce does not take place at an early age.

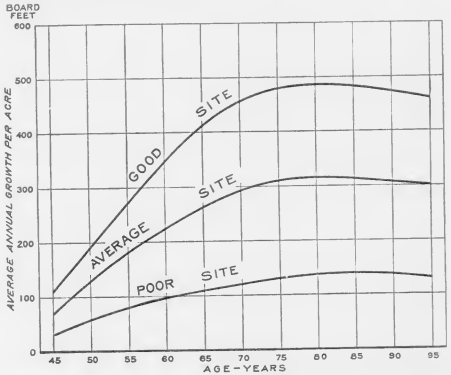


FIGURE 12.—Mean annual growth of fully stocked stands of second-growth red spruce in board feet per acre

The annual growth of pulpwood material as measured at 10-year intervals reaches its maximum at about 45 years, and the annual growth of saw-log material at 60 years. At these ages the periodic annual growth is as shown in Table 9.

TABLE 9.—*Periodic annual growth of pulpwood and saw-log material in their respective years of maximum periodic annual growth*

Product	Good site	Average site	Poor site
Pulpwood material in cords per acre at 45 years	2.23	1.74	1.13
Saw log material in board feet per acre at 60 years	1,160	740	325

The mean annual growth of more than four-fifths of a cord per acre on average sites and of more than 1 cord per acre on good sites, which is reached at 65 and maintained up to 75 years of age, indicates that the possible yields of pulpwood from red spruce are much higher than has been generally believed. The yields shown are particularly striking in view of the extremely slow seedling growth—15 years to breastheight. They occur, of course, only in fully stocked stands and are, therefore, not found over the considerable area of poorly stocked stands which make up the bulk of the present forest. They do, however, serve to indicate the possibilities, and could doubtless be increased under an intensive management which included one or more thinnings.

Yields of saw-log material, which on average sites amount to only 17,050 board feet at 65 and to 22,900 board feet at 75 years of age, with a mean annual growth of only 260 and 310 board feet, are much less satisfactory than the yields of pulpwood material. The difference is due to the fact that fully stocked stands of red spruce maintain a high density with a correspondingly small average diameter. The figures in Table 10 show for red spruce the number of trees per acre and the average diameter at 65 years of age on an average site.

TABLE 10.—*The number of red-spruce trees per acre and the average diameter at 65 years of age, average site*

Stand	Trees per acre	Average diameter
	Number	*Inches*
Total stand	980	6.5
Trees 4 inches d. b. h. and up	897	6.7
Trees 7 inches d. b. h. and up	390	8.2

Partially stocked stands approach a more fully stocked condition with advance in age. They usually average larger in diameter than fully stocked stands and contain a volume that is relatively high in proportion to the number of trees. This is particularly true of board-foot volume, which reaches its maximum with about 65 per cent of the number of trees needed to produce the pulpwood maximum. There is little doubt that in dense stands larger yields could be obtained in a shorter time by judicious thinnings, thus keeping the stands well stocked without overcrowding.

Mixed stands consisting chiefly of red spruce, with a scattering of white spruce and balsam fir, have practically the same yields as pure stands of red spruce. Both white spruce and balsam fir grow faster than red spruce in height, but are unable to maintain so complete a crown canopy. Balsam fir stands especially seem to break up after the early ages are passed, particularly on the poorer sites. For these reasons, although pure stands of white spruce or of balsam fir show larger yields in both cords and board feet in the early years, at approximately 60 years of age they are surpassed by red spruce. Balsam fir similarly shows a tendency to exceed white spruce up to about the same age, when the latter takes the lead.

NORTHERN HARDWOODS TYPE

The northern hardwoods type is common throughout the spruce and northern hardwoods region, where it ranks with the spruce types in area. Its commercial importance is usually high when near to good markets and low when at a considerable distance from them. River driving is more difficult than with conifers, because of the greater weight of the hardwoods which makes it impossible, without special treatment, to float them far. In the less settled parts of the region, where other means of transportation are lacking, many stands of intrinsically valuable timber can not be utilized profitably because of the cost of getting the product to market.

The type chiefly occupies moist but well-drained slopes and benches of medium elevation and all aspects. The soil is usually a sandy or clay loam of moderate depth. It is more fertile than most forest land, and where the slopes are not too steep nor the stones too abundant much of it is suitable for farming. The potato district of Aroostook County, Me., consists almost wholly of land formerly covered by the northern-hardwoods type.

Yellow birch, sugar maple, and beech are the most common and characteristic species. White ash and basswood are sometimes abundant locally, as, for example, in parts of the Green Mountains in Vermont. Red maple, hemlock, spruce, balsam fir, and white pine are usually present in varying amounts, with more or less paper birch in New England and sweet birch and black cherry in New York and Pennsylvania. (Pl. 9.) Repeated culling of spruce and balsam fir in the spruce-hardwoods type has often reduced the representation of these species so greatly as to convert many areas of originally mixed forest into the northern hardwoods type.

Virgin and culled stands in the latter type are typically uneven aged. "Wolf" trees with poorly formed trunks and widely spreading crowns are nearly always present and occupy a space out of all proportion to their value. Defect is also common, particularly in the butt logs. Second-growth stands, on the other hand, are typically even aged and are usually well stocked with thrifty young trees, although they are likely to contain more "weed" species, such as striped maple, aspen, and pin cherry, than do virgin stands.

NATURAL REPRODUCTION

Most of the species characteristic of the northern hardwoods type reproduce themselves readily. Large crops of seed are borne annually by yellow birch and sugar maple, and moderate quantities by basswood. At intervals of several years large crops are borne by white ash and small crops by beech (*21*). The seed of all five species is moderately fertile and germinates as well on humus as on mineral soil. Yellow birch often comes up quickly on burned areas. Beech and sugar maple will persist for many years under heavy shade. Yellow birch, basswood, and white ash require more light, but as seedlings they are sufficiently tolerant to thrive under a medium cover.

Because of these characteristics, seedling reproduction is ordinarily good under the more or less broken cover of the original forest.

Representation of the different species varies rather widely with the composition and density of the stand and with soil conditions. Sugar maple and beech predominate in very dense stands; white ash and basswood are common only on the better soils. Yellow birch is the least exacting in its requirements and is usually well represented where seed trees are present and where it is not crowded out by the more tolerant species.

Sprouts spring abundantly from most hardwood stumps of small or medium size. Those from larger stumps when present at all are seldom thrifty, except for basswood, which is able to produce sprouts that grow to log size from stumps as large as 2 or 3 feet in diameter. Beech sprouts rarely attain merchantable size. Sprouts from yellow birch, sugar maple, and white ash stumps less than 6 inches in diameter are usually vigorous but inferior in ultimate size and quality to seedlings. Sprout reproduction is unimportant in virgin or culled forests, but is generally abundant in second-growth stands (*21*).

METHODS OF CUTTING

Old growth and culled forests can be handled either by clear cutting or partial cutting. Clear cutting is, however, seldom practicable except where there is a ready market for fuel wood, acid wood, or small-sized material suitable for the manufacture of turned products. Elsewhere, the amount and quality of the lumber obtainable from the smaller trees is so low as to prevent their profitable utilization.

Clear cutting has the advantage of removing the competition of the mature trees for light and soil moisture, and thus giving ample opportunity for development to the abundant natural reproduction that is usually present. (Pl. 10, A.) It also favors particularly the more valuable white ash, basswood, and yellow birch, all requiring more light than either sugar maple or beech in order to make their most rapid growth. Clear cutting has the disadvantage of removing the immature trees which should be left for further growth and of creating a large amount of slash, which may retard, deform, or even kill a considerable number of seedlings. No attempts have been made, however, to burn hardwood slash, for in spite of its abundance it is so much less dense and decays so much more quickly than coniferous slash that the high cost involved in burning is hardly justified. Lopping of the slash, unless it is well scattered, is of no particular benefit to the seedlings, and even then is of doubtful value.

In clear cutting, the entire stand should be removed as completely as possible, including the small saplings. When weak and sickly, these are of little prospective value, are subject to serious injury by wind, snow, and ice, and are apt to interfere with the development of the more thrifty young growth; and when strong and vigorous they are likely to cause even greater interference by developing into "wolf" trees. Seedlings up to an inch or two in diameter should, however, be protected as carefully as possible from unnecessary damage, since it is these that form the basis for the next crop (*21*).

Partial cutting of old-growth stands, which in many localities is now enforced by economic conditions, produces material of higher

average value than does clear cutting. A recent experiment in the northern hardwoods type in the Lake States (no similar figures are available for the Northeast) showed that logs from a partial cutting, which removed few trees less than 22 inches in diameter, averaged $28.93 per thousand board feet in value as against $19 per thousand from an adjacent clear cutting. The partial cutting removed about half of the value of the original stand, but left two-thirds of its volume in the form of 181 trees per acre.

In the Northeast the cutting of merchantable trees down to an average diameter of about 12 to 15 inches is advisable. All "wolf" trees should be removed, in spite of the fact that they are apt to contain a large amount of defective material; if left they will interfere seriously with the development of the young stand. A few well-formed, thrifty trees above the diameter limit may well be left for seed production and those of the more valuable species, such as white ash or basswood, for further development. Poorly formed, suppressed, or unhealthy but still merchantable trees of all species below this diameter should be cut, as should also smaller trees of the less valuable species, such as beech. (Pl. 10, B.) Special pains should also be taken to remove individual trees or groups of trees which are suppressing advance growth of desirable species.

Avoidance of logging damage to reproduction and to thrifty trees of sapling or pole size is imperative.

Partial cutting of old-growth stands has the advantage of encouraging natural reproduction, and to some extent of influencing its composition, in stands where adequate advance growth is not already present. The relatively small amount of slash produced causes little injury to reproduction. Sufficient light is admitted to stimulate the growth of trees of all sizes in the remaining stand. And finally the larger saplings are not cut just at the time when their growth is at its height and when they are beginning to put on wood of higher quality.

An important disadvantage of partial cutting is the increased danger to the remaining stand from wind, sun, snow, ice, and insects. After even a moderately heavy cutting, the trees left are apt to become stag-headed as a result of drying out or of insect attacks. The bronze birch borer (*Agrilus anxius*) is a particularly dangerous enemy of yellow birch and paper birch, and the maple borer of sugar maple. Since both insects thrive best in trees exposed to full light, damage by them is usually severe wherever partial cutting is fairly heavy. On the other hand, too light a cutting has the disadvantage of stimulating but slightly the development of the younger seedlings, particularly of the more valuable species.

The old-growth stand left after the first cutting may later be cut clear, preferably when the bulk of the trees are large enough to furnish material of good quality but before they are so large as to interfere seriously with the development of the new crop. On the other hand, partial, or selection, cuttings may be continued indefinitely, and this course offers the opportunity of improving the composition of the stand by favoring the better individuals and species at each cutting. This is particularly important when such cultural operations as the clearing and thinning of young stands are impracticable.

Second-growth stands are, as a rule, near enough a market to permit complete utilization, and have in fact, usually resulted from an earlier clear cutting. They are characteristically even aged, and when well stocked have a rather uniform, dense crown cover which prevents an advance growth of young seedlings from coming in as abundantly as in the original forest. In such stands, reproduction after clear cutting is likely to be chiefly from sprouts. These grow rapidly at first, but, with the possible exception of basswood, are less desirable than seedlings, particularly from stumps larger than 6 inches in diameter.

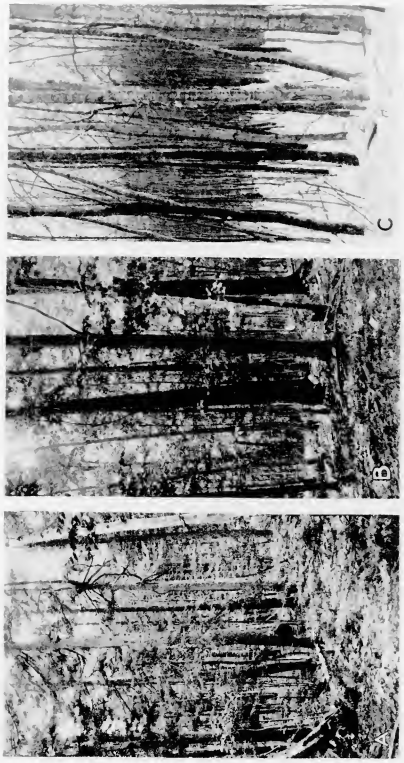
In even-aged stands without ample advance growth, best results will be obtained by a first cutting which removes about half of the volume. Well-formed, thrifty trees of the species which it is desired to favor (ordinarily white ash, basswood, and yellow birch) should be left, and other species cut as heavily as possible. Poorly formed, suppressed, and diseased trees of all species should be taken. This first cutting will open up the stand sufficiently to induce good seedling reproduction of the species favored. The remainder of the stand can then be cut clear after the new crop is well established, or removed in a series of partial cuttings. Seedlings of all the northern hardwoods will grow well for a while under light to moderate shade, but for their best development the second cutting should ordinarily be made within 10 years.

Sprouts will, of course, spring up after both cuttings. The first lot, however, will be held back by the overhead shade of the trees left, and by the time of the second cutting the seedlings should be large enough to hold their own with both lots. The final stand will then consist of a more or less even mixture of sprouts and seedlings.

The proportion of seedlings can be increased and the composition of the stand improved by cleanings similar to those described for the spruce-hardwoods type. These should be made when the seedlings are from 2 to 5 feet high. Seedlings of desirable species should be favored by cutting back both competing sprouts and seedlings of less desirable species. In order to obtain a fully stocked stand, it will nearly always be necessary to leave a fair proportion of sprouts, but these will do best if they are so thinned out as to leave only one straight, vigorous sprout to each clump.

The cost of such cleanings will ordinarily range from $2 to $4 per acre. Whether they will pay depends on the extent to which they are likely to increase the representation of the better species and consequently the stumpage value of the final stand. They should prove a profitable investment in stands located near good markets and containing valuable species that are likely, if unassisted, to be choked out by much less valuable trees.

Thinnings can also be used to advantage in older stands to favor the better species and to increase the rate of growth. Stands that start with a sufficient stocking to produce straight trees of high quality soon become too dense for their best development. When this point is reached, they can be greatly helped by thinning out the poorer individuals and less valuable species so as to give those that are left ample room for growth without opening up the stand so much as to waste space and to let in an undergrowth of grass and weeds. Thinnings can well start as soon as the trees removed are large



TYPICAL STANDS IN THE NORTHERN HARDWOODS TYPE

A, B, Advance reproduction of both conifers and hardwoods is coming in amply; C, a young stand of second-growth yellow birch.

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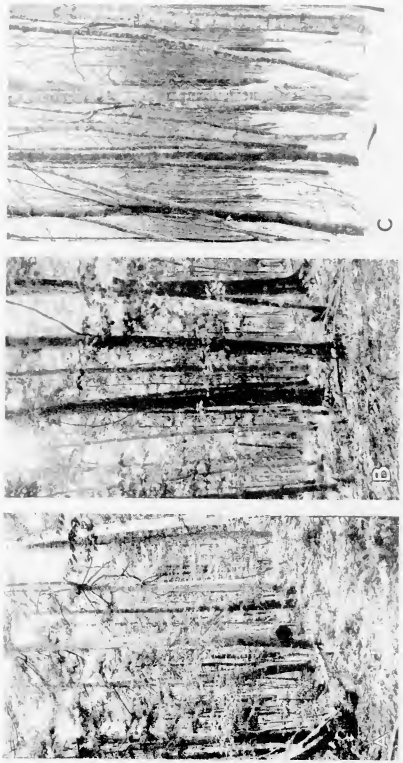

TYPICAL STANDS IN THE NORTHERN HARDWOOD TYPE

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CLEAR CUTTING AND THINNING OPERATIONS

A, Clear cutting for acid wood in the northern hardwoods type in Warren County, N. Y. Good reproduction from both seedlings and sprouts usually follows such cuttings; B, removing the inferior trees for fuel in a young stand in the northern hardwoods type in Rutland County, Vt. The remaining trees will develop more rapidly as a result of the thinning.

enough to cover the cost of the operation, and can be repeated whenever the stand becomes so dense as to result in decreased growth. They are not at present practicable throughout a large part of the type, but in accessible locations near to good markets may yield a substantial profit from the sale of the material removed.

Grazing of all sorts is highly injurious to hardwood reproduction, and should not be permitted in either old-growth or second-growth stands. Farmers desiring to raise both trees and livestock will find that they can do so most profitably by fencing the woodlot and by clearing up a piece of better land for exclusive use as pasture.

YIELDS

Old-growth forests in the northern hardwoods type, because of the large proportion of overmature and defective trees, are usually putting on little or no net growth. It is, therefore, advisable to put the land in a productive condition by removing the older trees and increasing the representation of younger, vigorously growing trees at the earliest opportunity.

The yield of second-growth stands varies with the site, the degree of stocking, and the relative abundance of the different species. Measurements in Vermont (*24*) of a large number of even-aged stands with the trees fairly uniformly spaced and without large openings gave the results shown in Table 11.

TABLE 11.—*Yields of well-stocked even-aged stands of second-growth in the northern hardwoods type, Vermont* [1]

Age (years)	Volume on good sites			Volume on average sites			Volume on poor sites		
	Cordwood	Saw logs plus cordwood		Cordwood	Saw logs plus cordwood		Cordwood	Saw logs plus cordwood	
	Cords	*Board feet*	*Cords*	*Cords*	*Board feet*	*Cords*	*Cords*	*Board feet*	*Cords*
20	17.4			14.4			10.9		
30	25.6			20.8			15.6		
40	33.3	3,500	24.1	26.7	2,000	21.2	20.2	1,000	17.1
50	39.9	9,900	22.9	32.8	4,500	22.9	24.4	3,000	21.2
60	45.3	13,800	20.6	36.5	8,200	22.6	28.1	6,600	17.6
70	49.5	15,100	18.8	40.0	10,900	20.6	31.2	9,100	16.2

[1] For composition of stands see text.

Cord volumes include the contents of the main trunk plus limb wood. They were first determined in cubic feet and then converted into cords on the assumption that there are 85 cubic feet of solid wood in a stacked cord of 128 cubic feet. Board-foot volumes were obtained with the Vermont rule by scaling all logs that were 6 inches or over in diameter at the top end, whether merchantable or not. Since many of the larger hardwoods are defective, the volumes shown must be reduced in accordance with the defect present in order to get the wood that could actually be sawed out.

The stands measured represented better than average conditions, but were not fully stocked and do not indicate the maximum obtainable. Their average composition was as follows:

Sugar maple	45 per cent	Beech	8 per cent
Yellow birch	18 per cent	Basswood	3 per cent
White ash	10 per cent	Others	16 per cent

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CLEAR CUTTING AND THINNING OPERATIONS

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30	25.6	.....	.....	20.8	.....	.....	15.6	.....	.....
40	33.3	3,500	24.1	26.7	2,000	21.2	20.2	1,000	17.1
50	39.9	9,900	22.9	32.8	4,500	22.9	24.4	3,000	21.2
60	45.3	13,800	20.6	36.5	8,200	22.6	28.1	6,600	17.6
70	49.5	15,100	18.8	40.0	10,900	20.6	31.2	9,100	16.2

[1] For composition of stands see text.

Cord volumes include the contents of the main trunk plus limb wood. They were first determined in cubic feet and then converted into cords on the assumption that there are 85 cubic feet of solid wood in a stacked cord of 128 cubic feet. Board-foot volumes were obtained with the Vermont rule by scaling all logs that were 6 inches or over in diameter at the top end, whether merchantable or not. Since many of the larger hardwoods are defective, the volumes shown must be reduced in accordance with the defect present in order to get the wood that could actually be sawed out.

The stands measured represented better than average conditions, but were not fully stocked and do not indicate the maximum obtainable. Their average composition was as follows:

Sugar maple	45 per cent	Beech	8 per cent
Yellow birch	18 per cent	Basswood	3 per cent
White ash	10 per cent	Others	16 per cent

The mean annual growth of these stands in cords and in board feet is shown in Figures 13 and 14. It is rather surprising that the maximum growth in cords should have been reached as early as at 20 years of age. This would seem to indicate that the stands, in spite of the fact that they were not regarded as fully stocked, must have been too dense in places at least, and that the rate of growth might have been maintained by judicious thinning. This is still more true of the growth in board feet, which reached the rather low maximum of 230 feet on site 1 at 60 years of age.

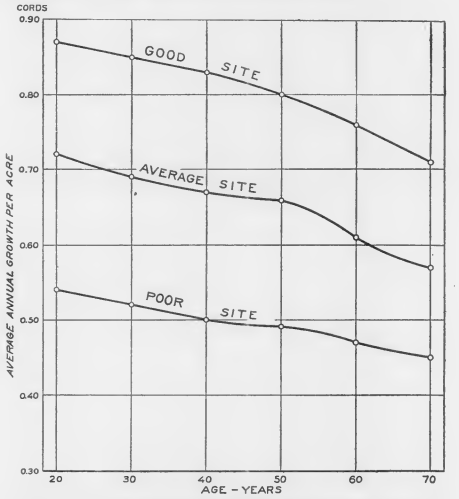

FIGURE 13.—Mean annual growth in cords of fully stocked, even-aged second-growth stands of northern hardwoods in Vermont

Additional information on yields under average conditions (*21*) is given in Table 12, which presents measurements of sample plots in well-stocked second-growth stands selected at random in other States. The cord volumes show merchantable fuel-wood material in trees 3 inches and over in breast-high diameter to a top diameter of about 2 inches, and were obtained by dividing cubic-foot volumes by 85. The crown density is shown in tenths, perfect density being 1. The crown density of birch, however, is seldom greater than 0.9, which may be considered perfect for that species.

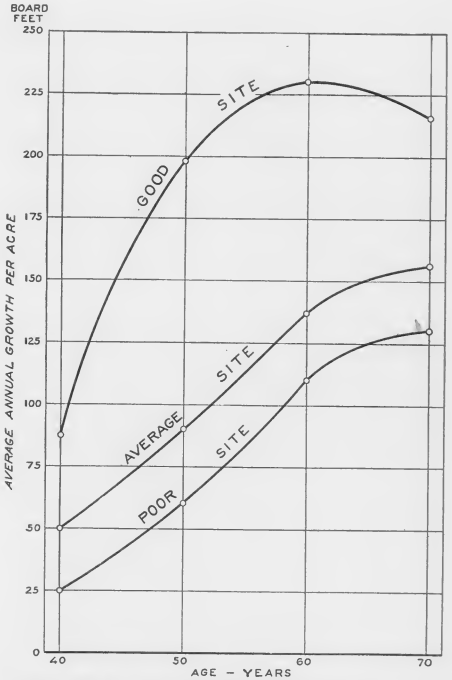

FIGURE 14.—Mean annual growth in board feet of fully stocked, even-aged second-growth stands of northern hardwoods in Vermont

TABLE 12.—*Yields of well-stocked second-growth stands of hardwoods in several States in the Northeast*

Location	Principal species and predominance in stand		Age	Crown density	Volume per acre	Mean annual growth per acre
		Per cent	*Years*		*Cords*	*Cord*
New Hampshire	Yellow birch	88	43	0.8	24.2	0.60
Do	do	78	75–80	.9	22.9	.29
Do	do	64	88	.9	38.6	.44
New York	do	56	20	.9	10.8	.54
Do	do	54	42	.7–.8	25.8	.61
Do	do	51	42	.9	30.6	.73
Pennsylvania	do	76	50	.85	10.9	.22
Do	do	85	80	.9	42.2	.53
New York	Sugar maple	78	39	1.0	28.0	.72
New Hampshire	Beech	58	70	.85–.9	22.9	.33
Do	do	92	95	1.0	33.1	.35

Recent studies in northern Pennsylvania indicate an average yield of about 1 cord per acre per year in fully stocked stands between 25 and 50 years of age (*26*). After 60 years the total volume increases very slowly. These yields are considerably more than can be expected under natural conditions over large areas, but are not unreasonable on good sites under intensive forestry.

BIRCH-ASPEN TYPE

Although the birch-aspen type is of minor importance in comparison with the types already discussed, it occupies a considerable area in the spruce and northern hardwoods region. It is most common in northern New England, where it is the chief source of paper birch for spools and other turned products and of aspen for pulpwood. Either of these characteristic species may form pure stands, or they may occur together in practically every degree of mixture. Pin (fire) cherry is often present, and there is sometimes a sprinkling of other hardwoods, notably yellow birch.

In New York and Pennsylvania the type is of decidedly minor importance in this region, both geographically and commercially. Paper birch is often entirely lacking, and pin cherry is a common and typical associate of the aspen.

Paper birch and aspen are both decidedly intolerant of shade and are able to establish themselves only on mineral soil. As a result they are poorly represented in the original forest. On the other hand, the exposed mineral soil and the absence of vegetation which are characteristic of freshly burned areas offer ideal conditions for reproduction, and the fact that both paper birch and aspen produce each year large quantities of very light seeds which are blown by the wind to great distances enables them to take prompt advantage of these conditions. For these reasons the type is not only common on burned-over lands, but is practically confined to them. It occasionally comes in on clear-cut areas where the mineral soil has been largely exposed by logging, but on such areas includes a much greater mixture of other species than is characteristic of burns.

Both species will grow on a wide variety of soils, although they thrive best on those of good quality. In Maine, for example, a

31-year-old aspen stand (*49*) on deep, loose, sandy loam had 672 trees per acre about 60 feet high and from 6 to 8 inches in diameter, while on a dry, gravelly ridge less than 10 rods away another stand of the same age had 1,224 trees per acre that averaged only about 25 feet in height and from 2 to 5 inches in diameter. On the poorest sites, particularly where the soil has been severely burned, some stands never attain merchantable size.

Because of the way in which it originates, the type always occurs in the form of even-aged stands. The light foliage of the trees and their inability to stand much crowding or overhead shade result in a comparatively light cover under which the more tolerant species reproduce readily. There is, therefore, nearly always an understory of spruce and balsam fir or, on the better soils, of sugar maple and yellow birch. These thrive under the light shade and eventually take possession of the area. Under natural conditions the type is thus a strictly temporary one. It serves a valuable purpose in reclothing burned land which might otherwise lie idle for a considerable period, but it is unable to perpetuate itself in competition with more tolerant and more persistent species.

METHODS OF CUTTING

Ordinarily, the owner of land in this type is glad to let it revert to the species which are naturally taking possession. Where this is so, all that is necessary is to clear cut the paper birch and aspen and thereby give the understory a chance to develop. (Pl. 11.) It is important, however, that the cutting be done before the stand is more than 70 or 80 years old, for older trees suffer badly from heart rot. A 95-year-old stand of aspen in Maine (*49*) had 8 cords per acre in standing dead trees, 3.4 cords in living but unsound trees, and 5.7 cords in sound trees. At least half of the wood in the unsound trees was probably so decayed as to be unmerchantable. If so, only 43 per cent of the total stand of 17.1 cords was still sound enough to be of any value. In an adjacent stand of the same age and running 32.9 cords per acre, cutting permitted a more accurate estimate; here the defect was 53 per cent.

If the stand is fully stocked, however, an earlier partial cutting preceding the clear cutting will save much material that would otherwise be lost. Because of the inability of paper birch and aspen to endure crowding, the mortality in such stands is high; also, the rapid decay of the dead trees renders them almost immediately unmerchantable. Much of this waste can be avoided and the remaining trees benefited by removing 20 to 40 per cent of the volume when the stand is 40 or 50 years old. The smaller, unthrifty trees which are likely to die before the next cutting, as well as the taller ones most liable to windfall, should be taken, leaving a moderately open stand of well-developed, vigorous trees with as uniform height and stocking as possible.

In the rare cases where reproduction of other species is not already present, clear cutting may be counted on to perpetuate the existing type. Paper birch up to 50 or 60 years of age reproduces vigorously by sprouts, and aspen up to 70 years by root suckers. These sprouts and suckers at first grow more rapidly than do seedlings,

but are even more intolerant of shade and unable to survive the competition of well-established advance growth of other species. When such competition is absent they readily restock the area, if cutting is done before the ages indicated. Aspen is especially prolific in this respect and often produces thousands of root suckers to the acre. Sprouts and suckers are so much shorter lived than seedlings that stands composed chiefly of them should be cut about 20 years earlier.

Where reproduction of other species is already present, but where the owner for some reason desires to continue the production of paper birch or aspen, the problem is much more difficult. Probably the most effective method of solving it would be to burn the area lightly after clear cutting. This would expose the mineral soil and thus restore conditions similar to those which produced the original stand of birch and aspen. Since aspen roots produce suckers freely after a light fire, a liberal representation of these can be expected in addition to reproduction by seed. It is, however, so difficult and expensive to get a burn of just the right intensity without endangering adjacent stands that the method can not be recommended.

The crowns of paper birch and aspen are so light and their utilization is ordinarily so close that only a comparatively small amount of slash results from clear cutting, and this decays rapidly. No special treatment of it is therefore necessary.

YIELDS

Table 13 gives yields of paper birch in merchantable material according to measurements on 46 representative areas (*14*) in Maine. All of the plots measured contained at least 40 per cent paper birch and had a density of over 50 per cent. Where other species were present the figures were reduced to correspond to a pure birch stand. Cubic feet were converted to stacked cords by dividing by 96, and it was assumed that 75 per cent of the total stand consisted of merchantable material.

TABLE 13.—*Merchantable volume of paper birch of average density, Maine; basis, 46 plots*

Age (years)	Volume on good sites	Volume on poor sites	Age (years)	Volume on good sites	Volume on poor sites
	Cords	*Cords*		*Cords*	*Cords*
30	13.3	7.9	60	30.8	22.0
40	19.6	12.4	70	34.8	25.8
50	26.1	17.3			

The yields given represent approximately what may be expected under natural conditions from pure paper birch stands of average density. Mean annual growth at different ages is shown in Figure 15. Aspen stands of the same age show considerably larger average diameters and somewhat higher yields. With both species yields could be increased by the thinning of over-dense stands wherever these are near enough a market to permit utilization of the material removed.

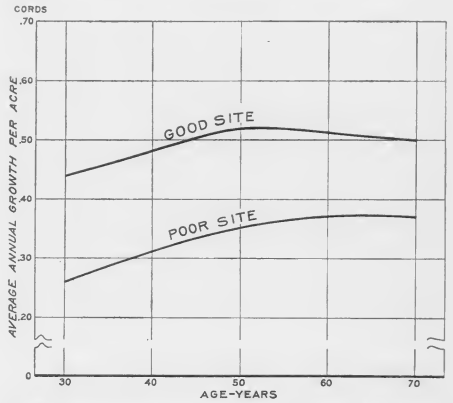

FIGURE 15.—Mean annual growth of pure paper birch in stands of average density

WHITE PINE REGION

The white pine region is characterized by the abundance of northern white pine, sometimes pure and sometimes in mixture with eastern hemlock and a wide variety of hardwoods. The composition of the present stands is strikingly different from that of the original forest, which consisted of a many-aged mixture of white pine and hemlock, with red oak, chestnut, white ash, and other hardwoods. White pine was less abundant than the hardwoods, but was prominent because of the occasional tall trees which towered above the rest of the stand. It has attained its present dominance by its ability to take possession of abandoned farm lands, which cover a large area in this region. This ability is shared with other less-valuable species such as gray birch, aspen, and red maple. These are much more abundant than formerly, and have frequently excluded white pine from areas which would otherwise be occupied by it. The principal forest types are white pine, pine-hardwoods, transition-hardwoods, and gray birch.

The region occupies chiefly the lower elevations in the more thickly settled parts of southwestern Maine, southern New Hampshire, southeastern Vermont, eastern and central Massachusetts, the Champlain Valley in Vermont and New York, and part of the Hudson

River Valley. It is typically a farm-wood-lot region with well developed transportation facilities and good markets.

WHITE PINE TYPES

The white pine type and the pine-hardwoods type are of outstanding importance in the white pine region. A survey by the Harvard Forest of seven representative towns in northern Massachusetts showed that the former constituted 36 per cent and the latter 14 per cent of the forest area of 108,000 acres (*1*). The commercial importance of both types is increased by their usual occurrence within easy reach of good markets.

Northern white pine comprises from 80 to 100 per cent of the white pine type, with varying amounts of pitch pine, Norway pine, eastern hemlock, oak, maple, birch, ash, and occasionally other species. This same group of trees is characteristic of the pine-hardwoods type, in which, however, there is always less pine and much more hardwood. Present stands, unlike those of the original forest, are chiefly even aged. Both types occur on a wide variety of soils and sites.

The pine-hardwoods type formerly covered a much larger area than at present, and in fact made up the bulk of the virgin forest throughout most of the white pine region. The stands were typically uneven aged, usually with scattered white pines under which grew a widely varying mixture of hardwoods and hemlock of all sizes. This mixed forest tended toward one of pine-hardwoods on the deeper, moister soils and toward one of pure pine on the lighter, drier sands.

As the agricultural and industrial development of the region advanced, the forest was cut more and more heavily for its timber, and large areas were cleared for farms. Since the Civil War, the process has been reversed. Farming has waned, the rural population has decreased, and enormous areas of once-cultivated lands have been abandoned, reverting for the most part to forest. Petersham, Mass., for example, which at one time had 60 per cent of its total land area in farms or pasture, now has 68 per cent in forest (*1*, *13*, *17*).

White pine and gray birch are the most aggressive species that restock these abandoned fields. The Harvard Forest survey showed that on the better soils 64 per cent and on the lighter soils 61 per cent of the old fields reverted to white pine, whereas on both sites 16 per cent reverted to gray birch. The white pine type is therefore common on abandoned farm lands, to which it is in fact almost wholly confined except on the lightest soils and occasionally on burned areas. Because of their origin, the white pine stands are even aged and are especially abundant in the more settled portions of the region, where they occur chiefly in the form of farm wood lots.

The ability of the white pine type to act as a pioneer in reclaiming cleared lands has very greatly extended the area occupied. There is every indication, however, that without some help these stands will seldom be able to hold their own. On the medium-to-better soils, there is a marked tendency for hardwoods to come in under

the pine, and thus in the next generation to restore the original pine-hardwoods type, or even to establish a pure-hardwoods type. Thus in the seven Massachusetts towns previously mentioned heavy cutting in the white pine type was followed by greatly increased representation of hardwoods on 75 per cent of the better soils and on 46 per cent of the lighter soils.

Under natural conditions, and except on soils too sandy for hardwoods, the white pine type, in spite of its present abundance, is distinctly temporary, marking the transition from cleared land to a stand more or less closely resembling the original forest. Even in the pine-hardwoods type, there is a tendency on the better soils toward increased quantities of hardwoods. The extent to which white pine is retained in both types, therefore, depends largely on the way in which the types are handled.

NATURAL REPRODUCTION

The abundance of white pine on old fields is due largely to the fact that its lighter seeds are blown to greater distances than those of any of the hardwoods except gray birch and aspen. Heavy crops of pine seed are usually borne at intervals of three to five years, and in the mineral or grass-covered soil the seeds find satisfactory conditions for germination and the seedlings for growth. Competition from such hardwoods as do start at the same time is likely to be reduced by the continuation of grazing on the otherwise abandoned fields.

In well-stocked stands of white pine, conditions become more favorable for the hardwoods. An ample seed supply of the lighter-seeded species is furnished by the occasional trees which are nearly always present even in pure stands of pine; and with the establishment of a forest cover the heavier-seeded species are introduced by rodents. When the stands begin to open up, as they usually do between 40 and 50 years of age, an advance growth of hardwoods commonly takes possession of the ground. These seedlings are fairly tolerant of shade and on good soils are able to persist until cutting gives them an opportunity for development (*13*).

White pine, on the other hand, is handicapped by its greater intolerance of shade and by the thick layer of pine-needle litter. This litter is a hindrance to all species, but particularly so to pine, since the roots of the slow-growing seedlings usually dry out in it before they are able to reach the mineral soil necessary for their survival.

The vitality and rate of growth of white pine seedlings under different degrees of shade are indicated by the figures in Table 14, taken from 10 sample plots of 1 square rod each in southern New

TABLE 14.—*Survival and rate of growth of northern white pine seedlings under different degrees of shade in southern New Hampshire; basis, 10 plots of 1 square rod each*

Degree of shade	Average per plot, 1905	Living in 1909	Total height growth, 1905–1909
	Number	*Per cent*	*Inches*
Dense crown cover	271	5.5	3.0
Broken crown cover	102	60.8	8.5
Open crown cover	100	94.0	9.5

Hampshire (*20*). These seedlings, which had been badly suppressed and were therefore gaining very slowly, averaged 1.5 feet in height on all of the plots at the time of their establishment in 1905, and conditions were similar in other respects, except as to shade.

Even in the open, the development of white pine in early youth is much slower than that of the hardwoods, which are nearly always abundant on cut-over areas. The difference in growth is shown graphically in Figure 16, which is based on the measurement of trees with ample opportunity for development on good soils in southern New Hampshire and Massachusetts (*13*). "Seedling sprouts" are those from stumps of 0.5 inch in diameter or less. Sprouts from larger stumps have even more rapid growth.

A similar comparison is afforded by the figures in Table 15, based on about 800 trees not retarded by overhead shade on good soil in northern Massachusetts (*16*).

TABLE 15.—*Comparison at different ages of heights of open-grown northern white pine seedlings and hardwood sprouts in northern Massachusetts; basis, 800 trees*

Age (years)	White pine seedlings	Red oak, white ash, chestnut, and sugar maple sprouts	Red maple, gray birch, and aspen sprouts	Age (years)	White pine seedlings	Red oak, white ash, chestnut, and sugar maple sprouts	Red maple, gray birch, and aspen sprouts
	Feet	*Feet*	*Feet*		*Feet*	*Feet*	*Feet*
1		2.2	3.2	4	1.5	8.2	9.0
2	0.4	4.5	5.3	5	3.0	11.0	11.0
3	.8	6.8	7.3	6	4.0	13.5	14.3

Table 15 is also of interest as showing the more rapid growth of the "weed" species as compared with the better hardwoods. After the white pine is thoroughly established, its height growth increases materially, often exceeding 3 feet a year. It is, therefore, able to hold its own if it can escape being crowded out while it is obtaining a foothold.

White pine reproduces more freely in the lighter litter of the pine-hardwoods type than in the white pine type, but here the hardwoods are also more abundant and competition from them more intense. With their much more rapid initial growth in height and crown area, the hardwoods are almost certain to predominate in the next crop. White pine stands its best chance for development where it occurs, as it often does, in small groups. Under natural conditions these groups are gradually reduced in size by the encroachment of the hardwoods. One or more trees in the center of the group usually persist, however, to form a part of the final crop, and the crowding to which they have been subjected improves the quality of their product. The development of such a group is indicated in Figure 17 (*13*).

METHODS OF CUTTING

The large yields obtainable from white pine, the fine quality of its wood, its high stumpage value, and its usual occurrence in close proximity to good markets have all combined to arouse interest

in its perpetuation and improvement. As a result, the white pine type and the pine-hardwoods type have probably received more study and attention than any others in the Northeast.

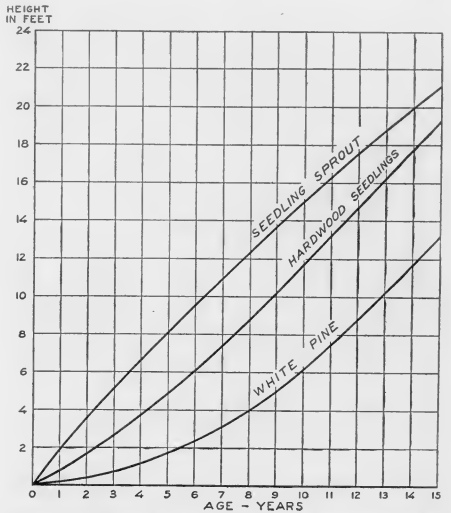

FIGURE 16.—Relative height growth of white pine seedlings, hardwood seedlings, and hardwood seedling sprouts

Until recently the general tendency was to handle every stand with the object of obtaining the greatest possible amount of white pine. It is now being realized that this may be good policy only on the lighter soils that are not well adapted to hardwoods. Elsewhere, the maintenance of a mixed forest similar to that which was originally characteristic of the white pine region, and to which second-growth stands are steadily reverting, is likely to be easier and in the long run more profitable. In addition to its other advantages, a mixed forest improves the quality of the soil, produces higher grade timber, and is usually less liable to injury from insects and disease than is one of pure pine.

Both the white pine type and the pine-hardwoods type can be handled most advantageously by the so-called shelter-wood method,

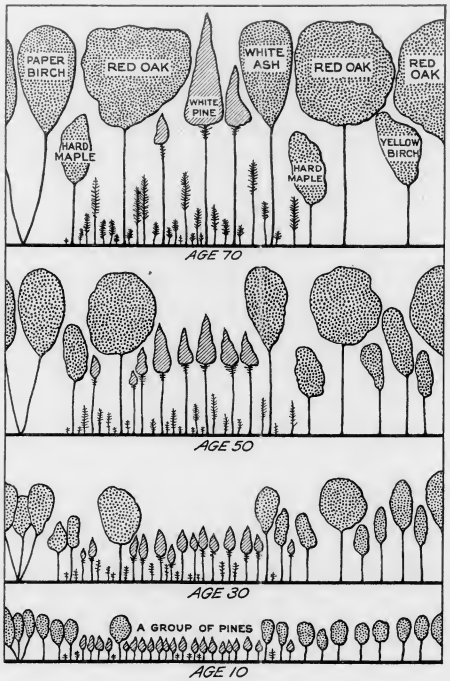

FIGURE 17.—The development of white pine grouped among hardwoods. (Courtesy of the Harvard Forest)

by which the mature stand is removed in two (or occasionally three) cuttings several years apart. (Pl. 12.) The first cutting should remove from 40 to 50 per cent of the crown canopy, including both the smaller, less thrifty trees and those with large, spreading crowns which would do much damage if felled after reproduction had become well established. The trees left should be well developed, with medium-sized crowns capable of ample seed production and of increased growth; and in mixed stands white pine should be favored. Logging should, if practicable, be done when there is no snow on the ground, so that the litter and humus may be torn up as much as possible (*13*).

This opening up of the stand will stimulate the development of reproduction already on the ground, will result in the establishment of new reproduction of both pine and better hardwoods, and at the same time will not admit enough light to encourage the more intolerant weed species such as gray birch, aspen, and pin cherry. White pine nearly always comes in abundantly, particularly if the mineral soil is well exposed, and not infrequently runs as high as 25,000 or more seedlings to the acre.

The remainder of the stand should preferably be cut clear when the reproduction resulting from the first cutting is from 4 to 6 years old (*13*). If the final cutting is made earlier, more pine seedlings are likely to be killed by the pales weevil and by the drying out of the surface soil; whereas if the cutting is delayed, the seedlings are likely to become stunted and unable to take prompt advantage of the increased light. Where there is an abundant advance growth of hardwoods, these seedlings are often misshapen and should be cut back to the ground to give the pine a better chance and to insure development of straight, vigorous seedling sprouts. Cleaning can usually be done with a bush scythe at the rate of an acre to an acre and a half per man per day. The cost is more than offset by the increased ease of logging.

On areas where the soil is light and the stand is more or less uneven aged, a heavier first cutting can be made to favor the smaller trees. Here there is less danger that the pine seedlings will be choked out by hardwoods or suppressed by the relatively light overhead cover even if the second cutting is deferred for several years. The smaller trees can, therefore, be left long enough to increase materially in size and diameter. Best results will, of course, be obtained by leaving only thrifty trees that are able to take advantage of the increased growing space. On a tract in New Hampshire where the stand was cut to a fixed diameter limit of 8 inches on the stump, no windfall resulted, and 14 years later some of the trees had increased to a 20-inch stump diameter. Reproduction is often good, particularly if a few of the larger trees are left to serve as seed trees.

In stands of this sort, the increased cost of partial cutting as compared with clear cutting is more than offset by the higher quality of the timber removed. A good example of this is afforded by two practically adjacent lots in southern Maine—one in private ownership, the other owned by Bates College. On the privately owned lot, where clear cutting was practiced at a cost of $10 per thousand board feet for logging from the stump to the cars, 70 per cent of the lumber was of such low grade as to be suitable only for box boards

or framing. On the Bates College lot only the mature trees, comprising about 65 per cent of the stand, were removed. The cost of logging was $2 per thousand more than on the clear-cut lot, but fully 80 per cent of the timber went into square-edged lumber of high grade.

Clear cutting may result in satisfactory reproduction of pine in the comparatively rare stands where a satisfactory understory of pine is already present, or when the cutting is done during a good seed year. (Pl. 13.) Since white pine seeds require two years to mature, it is possible to determine the probable production of seed a year in advance, but it is not always possible to arrange logging operations so as to take advantage of this knowledge. When cutting can be arranged to coincide with a good seed crop, it should be done after the seeds have fallen, which is usually in September. If done before, the seeds will for the most part be buried in slash piles, or destroyed completely if the slash is burned. (Pl. 14, B.)

A study by the Harvard Forest (*18*) of 54 cut-over areas representing upwards of 4,000 acres in northern Massachusetts and southern New Hampshire threw the following light on the results of clear cutting. Of the 54 separate areas examined only 14 had a satisfactory reproduction of pine, or as many as 500 thrifty seedlings per acre. All of these 14 lots were cut in seed years, in the autumn or winter following the fall of the seed. Two other lots cut in seed years showed no reproduction, the failure being due to the fact that the previous stands were unusually dense and below the seed-bearing age. The remaining wood lots were cut over in nonseed years; of these only 10 showed any pine reproduction at all, and only 1 out of the 10 anything like a sufficient seeding. There was no evidence of reproduction from seed stored in the leaf litter more than 1 year, and if seedlings failed to start within from 1 to 5 years after the cutting, the development of other vegetation kept them out entirely. In all, about 15 or 20 per cent of the total area of the wood lots examined supported good pine reproduction, and on another 20 per cent pine seedlings were scattering. On the other hand, 60 to 70 per cent of the area cut in both seed years and nonseed years was satisfactorily stocked with valuable hardwoods, such as red oak, white ash, and sugar maple.

Satisfactory reproduction of white pine is, therefore, rarely obtained when clear cutting is done in nonseed years, and even in seed years is less certain than under the shelter-wood method. The chances of success in nonseed years are somewhat increased by leaving four or more seed trees to the acre. These should be 10 inches or more in diameter and should have good-sized, well-developed crowns capable of producing an ample supply of seed of good quality. Small, poorly developed trees, such as have often been left, bear little or no seed.

CLEANINGS AND THINNINGS

Whatever method of cutting is used to start the new stand, subsequent "cleanings" will ordinarily be necessary to maintain the desired proportion of white pine and better hardwoods and to give them ample opportunity for development. The study of the cut-over areas just referred to indicated that however successful the reproduction may be at the start, under natural conditions, 10 years later 10 to 80 per cent of the desirable elements, both pine and hardwood, is liable to be overtopped and suppressed by inferior species and clumps of stump sprouts. (Pl. 14, A.)

In both the white pine type and pine-hardwoods type such undesirable species as red maple, gray birch, and aspen are usually present after cutting, and because of their more rapid height growth interfere seriously with the production of fully stocked, rapidly growing stands of white pine, white ash, red oak, yellow birch, black cherry, sugar maple, basswood, and other valuable hardwoods.

Table 16 gives the reproduction one year after final cutting by the shelter-wood method and five years after clear cutting (*16*, *18*) on two representative areas in the pine and hardwoods type. Although pine and valuable hardwoods were present in sufficient numbers to form an excellent stand, there was little chance of their being able to do so unless afforded some relief from the competition of the 10,040 red maples on the shelter-wood area and from the 2,640 red maple, gray birch, and aspen on the clear-cut area. Both red maple and gray birch reproduce readily on a wide variety of soils, but with a tendency for the maple to predominate on the better and the birch on the poorer sites. The comparatively heavy foliage of the maple increases the danger of suppression, and the slender twigs of the birch do much damage to neighboring pines by whipping off their leaves and buds.

TABLE 16.—*Reproduction in the pine-hardwoods type following logging by the shelter-wood method and clear cutting*

Species	Trees per acre 1 year after shelter-wood cutting		Trees per acre 5 years after clear cutting[1]	
	Number	*Per cent*	*Number*	*Per cent*
White pine	3,350	18.0	980	9.1
White ash	2,400	12.9	2,020	18.7
Black cherry	1,250	6.7	2,960	27.4
Red oak	570	3.1	960	8.9
Other valuable hardwoods	850	4.6	1,250	11.6
Red maple	10,040	54.0	500	4.6
Gray birch	130	.7	990	9.1
Aspen			1,150	10.6
Total	18,590	100.0	10,820	100.0

[1] Includes only the number of clumps of seedling sprouts and stump sprouts.

Experience shows that where the weed species are abundant they should ordinarily be cut back when they are about 3 to 5 years old, and 5 to 8 feet high. White pine reproduction resulting from clear cutting will then be hardly a foot high; that obtained by the shelter-wood method will average about 3 feet. Both seedlings and sprouts should be removed wherever they are interfering with white pine, valuable hardwoods, or hemlock, but they need not be cut where they themselves are clearly becoming suppressed. In some species, particularly aspen, cutting the stem only part way through and then bending the top down to the ground has apparently decreased the vigor of the succeeding sprouts. Hemlock should be favored not because of any expectation that it will form an important part of the final crop, but because of its value in killing off the lower limbs

and thereby increasing the quality of the associated pine and hardwoods.

On sites where the reproduction contains a large proportion of valuable hardwoods, some of these will also have to be removed if it is desired to maintain a mixed stand of pine and hardwoods. If so, advantage should be taken of the usual tendency of white pine to occur in groups. If these groups are saved from suppression by cutting back all of the hardwoods within them, they will eventually produce one or more pines of high quality. Between the groups of pine the better hardwoods should be favored by removing the weed species and the less desirable trees of all species.

On good soils a second weeding will usually be necessary in about five years, when the hardwoods will again be overtopping the pine. This is particularly true if the pine seedlings are less than 3 or 4 feet high at the time of the first cleaning, as they usually are after clear cutting. The second cleaning should be of the same general character as the first, but may not need to include quite so many trees. By 10 years of age the pine has normally attained a rate of growth approximately equal to that of the hardwoods. Two cleanings are, therefore, usually sufficient to enable it to hold its own, although three may sometimes be necessary on the best sites, where hardwoods make their most rapid growth.

The cost of cleaning ranges from about $2 to $8 per acre, depending on the number and size of the hardwoods present and on the care with which the cleaning is done. On the Harvard Forest, cleanings undertaken before the hardwoods have passed the small sapling stage have been done at the rate of 1.5 to 2.5 acres per man per day. Areas which have been cleaned twice and which are in condition to produce valuable timber without further expense have ordinarily cost from $7 to $9 per acre (*18*).

On light sands, where hardwood competition is less intense, cleaning can be deferred until the pines are from 4 to 5 feet high. By this time the hardwoods will be large enough to use for fuel wherever there is a market for small-size material. Cleanings in such stands on the Yale Forest in southwestern New Hampshire have frequently been made not only without incurring any net cost but at a profit of from $0.50 to $1.50 per cord for the material removed. Under such circumstances one cleaning may be enough to assure a good stand of pine, particularly where gray birch is the predominant hardwood; but as a rule a second cleaning will materially increase the rate of growth of the pine. Badly suppressed pines usually require a year to adjust themselves after being released, but thereafter develop rapidly.

Cleaning has not yet been practiced long enough to make available exact figures as to its effect on yield. In many cases, however, observations of adjacent and originally similar stands make it clear that the large proportion of white pine which is now certain in the final crop as a result of cleaning would have been greatly decreased or entirely eliminated without such assistance. Equally good results are often obtained with the more valuable hardwoods, their representation in the stand being much greater than it would have been with unrestricted competition of the inferior species. In general, cleaning improves the composition of the stand in much the same

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FIRST STEP IN THE CONVERSION OF THE BIRCH-ASPEN TYPE TO CONIFERS

The paper birches which constitute the bulk of the stand are comparatively short-lived trees and will be gradually replaced by the more tolerant and persistent spruce and balsam fir seedlings. (Grafton County, N. H.)

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FIRST STEP IN SHELTER-WOOD CUTTING

A well-stocked stand in the white pine type without advance reproduction before (A) and after (B) a shelter-wood cutting has been made to stimulate reproduction. The remainder of the stand will be removed after the reproduction has become well established. (Photographs by courtesy of the Harvard Forest.)

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WHERE ADVANCE REPRODUCTION IS PRESENT, RESULTS OF CLEAR CUTTING IN WHITE PINE ARE GOOD

A, Excellent advance reproduction in a white pine stand ready for cutting in Merrimack County, N. H.; B, the result of clear cutting in a stand in Cheshire County, N. H., where white pine reproduction was already well established, as in A.

FIRST STEP IN SHELTER-WOOD CUTTING

A well-stocked stand in the white pine type a short time before (A) and after (B) a shelter-wood cutting has been made to stimulate reproduction. The remainder of the stand will be removed after the reproduction has become well established. (Photographs by courtesy of the Harvard Forest.)

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A, A stand of white pine in need of thinning. By taking out the inferior, less thrifty trees in this stand in Belknap County, N. H., the growth of those left can be considerably increased. B, Clear cutting in the white pine type without advance growth. This practice is unlikely to give satisfactory results. Reproduction is impossible under the heavy piles of slash, and these piles are also a serious fire menace. (Cheshire County, N. H.)

way as would planting, and it has the great advantage of being much cheaper. Indeed planting must often be supplanted by cleaning in order to assure the establishment and satisfactory development of the plantation.

A crude form of cleaning may be practiced by allowing stock to graze on cut-over areas. Both cattle and sheep browse on the hardwoods and thus tend to favor the white pine, in spite of some injury to the latter by trampling (*46*). While grazing is thus a cheap and partially effective method of saving considerable pine from suppression, it is also very apt to result in serious damage to the better hardwoods, and is much less satisfactory than cutting.

Early cleanings should be supplemented by later thinnings to prevent overcrowding. The maintenance of a fairly dense stand at all ages is essential in order to make full use of the productive capacity of the soil and to grow timber of high quality; but the number of trees necessary to do this decreases steadily as the stand becomes older. Thus, a pure pine stand which starts with 10,000 trees to the acre may be well stocked with less than 300 trees when it is 60 years old. Under natural conditions this reduction in numbers is brought about by the intense competition which exists in crowded stands, but is usually accompanied by complete loss of the material in the trees which drop out and by decreased growth in those which remain. Better results can be obtained less wastefully if the competition is relieved by judicious thinnings.

To obtain the best results, the first thinning should be made soon after real crowding begins, which on good soils may be as early as 15 years, and in the majority of well-stocked stands by 20 or 25 years of age. A good general rule is to start the work as soon as the material to be removed can be marketed without loss; too long a delay is likely to find white pines with such small crowns as to prevent them from making the increased growth of which they would earlier have been capable.

In thinning white pine and hardwoods both, the object should be to favor the thriftier, better-formed trees. This can be done by removing most of the smaller and intermediate individuals and enough of the larger ones to afford ample growing space for those that are left. Badly suppressed trees, however, need not be removed, since they no longer interfere with the development of the stand but help to promote natural pruning. Hemlock is also valuable for this purpose and should usually be left. Trees which are markedly taller than their neighbors, particularly hardwoods, should be cut to prevent their developing into "wolf" trees, as should also undesirable hardwoods and poorly shaped, unthrifty, and defective individuals of all species.

In less than five years white pine will ordinarily fill up completely a space of 3 to 5 feet between adjacent crowns. Larger openings will occasionally be necessary, but they should be avoided as much as possible because of the probability that they will produce limby trees of relatively poor quality. For naturally narrow-crowned hardwoods such as white ash, more room for expansion should be provided than for broad-crowned species such as red oak. In mixed stands a special effort should be made to give every

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opportunity for development to groups of white pine and to particularly promising hardwoods.

The results to be obtained from thinnings are indicated by certain experiments (*25*) in southwestern New Hampshire which have been under way since 1905. One plot was left unthinned, and a second was lightly thinned and the third heavily thinned in 1905, 1915, 1920, and 1925. All three plots were in a 35-year-old stand of pure white pine on sandy soil of rather poor quality. The influence of the thinnings on volume and on rate of growth is shown in Table 17.

TABLE 17.—*Influence of thinning on volume per acre and rate of growth during a 20-year interval, 1905–1925*

Character of plot	Volume before thinning	Volume removed	Volume 20 years after thinning	Total yield [1]	Mean annual growth per acre
	Board feet	*Board feet*	*Board feet*	*Board feet*	*Board feet*
Unthinned	14,256		30,520	30,520	813
Lightly thinned	13,684	10,056	21,608	31,664	929
Heavily thinned	14,664	15,204	17,502	32,856	910

[1] This is the volume in 1925 after thinning, plus the quantity removed in thinnings.

Although the 1925 volume in the unthinned stand is considerably greater than in either of the others, if the large volume removed in thinnings is taken into account, it is evident that the thinned stands lead both in total production and in rate of growth. Moreover, the present volume is concentrated on a much smaller number of trees of larger size and better quality. On the basis of the reduced capital left after the thinning in 1905, the mean annual growth has been 8.6 per cent in the lightly thinned plot and 7.8 per cent in the heavily thinned plot, as against 5.7 per cent in the unthinned plot.

Thinning experiments at the University of New Hampshire show that at ages between 30 and 50 years it is possible to remove from well-stocked white pine stands an average of 1 cord per acre per year, and at the same time increase the rate of growth of the remaining trees. In certain plots where this has been done for 12 years, there is now 20 per cent more volume than in adjacent unthinned plots with twice the number of trees.

Another example of the possible profit from thinning is offered by a tract under private ownership in southern Maine. Here, 5,540 board feet and 14 cords of wood per acre were removed from a sample plot at a net profit of $78.80 per acre. In addition to this profit the thinned area is now in better condition and will grow more rapidly than the adjacent unthinned forest.

Artificial pruning of white pine offers another means of increasing considerably the value of the final crop. Trees in open-grown stands retain their limbs almost indefinitely and have so many and such large knots as to reduce greatly the value of the lumber produced. Natural pruning gives better results in well-stocked stands, particularly when the pine is mixed with hardwoods or hemlock, but even dead limbs are retained for many years and decrease the amount of clear lumber when cutting is done before 60 or 70 years of age, as is now usually the case.

If all limbs are removed from the lower 16 feet of a tree when it is 3 or 4 inches in diameter, clear lumber will be produced by the butt log from then on. They should be cut off clean and close to the bark, preferably with a short crosscut saw mounted on a long pole. When the work is done in this way the wound heals over quickly and there is little danger of forming pitch streaks or pitch pockets or of starting decay. Unsatisfactory results are usually due to careless pruning with an ax or club, and particularly to the leaving of projecting stubs. Only the best trees which are to form part of the final crop should, of course, be treated.

Experiments by a private owner in central New Hampshire (*6*) covering a period of 20 years indicate that one man with a saw can prune 100 feet of stem, or six 16-foot logs, per hour. At 50 years of age these logs should yield about 1,000 board feet of lumber of high quality. In one instance the lumber sawed by this owner from pruned logs brought $65 a thousand feet, when he was having difficulty in selling box boards from similar unpruned material for $25 a thousand. In general, the skilful pruning of well-selected stands of white pine may increase the value of the final product from $15 to $35 a thousand feet, in addition to 6 per cent compound interest on the investment. On the other hand, the pruning of trees which are poorly formed or over 6 inches in diameter is likely to prove very unprofitable (*12*).

Because of the common occurrence of the white pine type and the pine-hardwoods type in the vicinity of good markets, cleaning, thinning, and pruning are all practicable operations in most stands. Thinning, in fact, can usually be counted on to yield a substantial profit. Improvement of the forest by these means should prove especially profitable and worth while on the farm wood lot, since it can be done to advantage during the winter when scarcity of other work affords ample time for the owner to handle it himself with little or no cash outlay.

SLASH DISPOSAL

With utilization to a 5-inch top diameter, as is now common with white pine, a large amount of slash is left after logging in well-stocked stands. A survey of seven towns in north-central Massachusetts shows that about 40 per cent of the total area of cut-over land in the white pine type is covered by slash (*1*). This is for the most part in piles and windrows which are dense enough to keep out all reproduction, often for as long as 20 years. Some method of reducing the amount of slash is, therefore, essential for the production of well-stocked stands.

Wherever the market for fuel permits, the cheapest and most satisfactory method of slash disposal is to cut up and sell the tops for this purpose. From two-fifths to 1 cord of fuel wood can usually be obtained for every thousand board feet of lumber cut. This method has been used successfully on the Bates Forest, in southern Maine (*37*), and on the Yale Forest, in southwestern New Hampshire. The net profit from the material cut from the tops averages from 25 to 50 cents per cord and occasionally runs as high as 75 cents. Taking out the cordwood so greatly reduces the amount

of material that no further disposal is necessary, particularly if the branches which are too small to be utilized are well scattered.

In clear cuttings where the sale of fuel wood is not practicable the slash can either be burned as logging proceeds or thrown into large piles or windrows for subsequent burning. The latter method is cheaper, but there is greater danger that the fire will get out of control. It also destroys both existing reproduction and seed on a much larger part of the area.

In shelter-wood cuttings the slash should preferably be gathered in small piles and burned as the logging proceeds. Burning will thus be confined to the smallest possible area, with minimum injury to the remaining stand at the first cut and to reproduction at the second cut.

Costs of slash piling and burning are influenced by a large number of factors, chief among which are the size and form of the tree crowns. These may vary from 15 to 50 feet in length and correspondingly in width in stands of the same age but of different density and composition. As a rule, the cost varies from about $0.50 to $1.25 for every thousand board feet of timber cut. It averages considerably higher on areas cut by the shelter-wood method than on clear-cut areas, especially when the slash on clear cuttings is burned in windrows (*13*). On the other hand, the clearing up of the area effected by burning in small piles as logging proceeds may materially reduce the cost of logging by the shelter-wood method. Slash disposal is now practiced only on isolated cuttings, and costs may be expected to decrease as its use becomes more general. Elsewhere, experience and a genuine desire to do a good job have been found decidedly effective in this respect.

Where there is a market for fuel, hardwood tops should be cut up and sold in the same way as white pine. Elsewhere, no special effort need be made to dispose of them, since they decay rapidly and are so open that they seldom interfere seriously with the establishment of natural reproduction.

DISEASE AND INSECT CONTROL

The white pine blister rust (*Cronartium ribicola* Fischer) is a fatal disease of 5-needle pines which must be controlled if white pine is to be grown commercially as a crop (*42*, *43*). This fungus was introduced from Europe on nursery stock about the beginning of the present century, and is now firmly established in the Northeast. It attacks white pine trees of all ages, but is particularly destructive of young reproduction.

The disease can not spread directly from one pine to another, but must spend a part of its life on the leaves of currants or gooseberries. It can, therefore, be controlled by the eradication of these bushes. Cultivated black currants are particularly dangerous in spreading the disease, and should not be grown in white pine regions. All other currants and all gooseberry bushes, both wild and cultivated, should be uprooted within 900 feet of white pine stands. To prevent sprouting, the entire root, particularly the crown, of each bush must be pulled up; it is not sufficient to cut back the tops. After a period of from 3 to 7 years, depending on conditions, the ground

should be reexamined and any regrowth of currant or gooseberry bushes destroyed. The cost of the initial control work will vary from 10 cents to $2 per acre, depending chiefly on the number and size of the bushes, density of undergrowth, and topography. On 6,837,385 acres cleared of such bushes in New England and New York from 1918 to 1928 the cost averaged only 21 cents per acre. The cost of any reeradication work will be much less.

Such measures are absolutely essential if the production of white pine is to continue. The cultivated black currant is so dangerous that its growing should be prohibited by law and the destruction of all existing bushes required. The State forester, or other appropriate official, should be authorized to establish quarantines against planting within the State other species of currants and gooseberries, and to require the eradication of existing bushes wherever their presence endangers either present or prospective stands of white pine. Legislation along these lines is already in effect in most of the Northeastern States. Timberland owners and others should, of course, take steps to eradicate currant and gooseberry bushes from their lands, either on their own initiative or in cooperation with the State authorities.

There are also two insects which must be taken into consideration in the growing of white pine. One of these, the pales weevil (*Hylobius pales*), or snout beetle, is usually abundant on recently cut-over areas, to which it is attracted in large numbers by the odor of white pine stumps, slash, logs, or lumber (*33*). The adult beetles feed voraciously on the bark of young trees, which they kill in a few days. Two and three year old seedlings are preferred and are more easily girdled than those of larger size. Serious damage is seldom done even to trees over 3 feet in height.

The pales weevil migrates freely and is attracted from long distances to freshly cut areas. Here it does most of its damage during the first two years after cutting. Two illustrations of this fact and also of the extent of the damage may be cited from the Harvard Forest (*7*). Three years after a broken stand of limby, pasture-grown white pine had been removed from over a veritable carpet of pine reproduction from 2 to 6 inches high, with very few hardwoods present, not more than 10 per acre of these thousands of young pines were still alive. In another case a plantation of 3-year-old white pine transplants were established in May, 1914, on an area from which a heavy stand of white pine had been cut clear the previous winter. By the fall of 1915, 71 per cent of the planted trees were dead or dying as a result of injury by the pales weevil. (Fig. 18.)

Control of the weevil is difficult. Burning of white pine slash removes a large amount of the material which helps to attract it to cut-over areas; and if the burning is done over pine stumps it will lessen their attractiveness as breeding places. Logs and lumber should also be removed promptly from areas where reproduction is desired. These measures will not prevent an infestation, but will mitigate it.

Where the weevil is a serious menace, the only other safeguard is to obtain natural reproduction in such abundance that a loss of from 50 to 75 per cent will still leave enough seedlings to form the basis for a satisfactory crop. This can usually be attained in successful

cuttings by the shelter-wood method, and with the additional advantage that by the time of the second cut the seedlings are getting beyond the stage where they are most susceptible to serious injury. Where clear cutting results in immediate reproduction, as in a good seed year, the bulk of the damage is limited to the second year after cutting, since 1-year-old seedlings are seldom attacked.

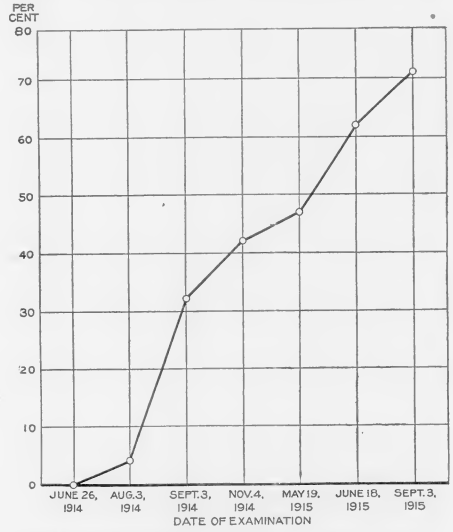

FIGURE 18.—Progress of injury by the pales weevil in a white plantation during the first two years after its establishment

Pine plantations can not safely be set out on cut-over pine areas until the third year after cutting, by which time hardwoods are likely to have obtained a sufficient start to necessitate subsequent cleanings. This applies also to plantations of other conifers, nearly all of which, though less susceptible than white pine, are subject to more or less serious injury, particularly if white pine is absent. For example, in plantations of Norway pine and Norway spruce, 48 per cent and 25 per cent of the trees were killed by the pales weevil during the first year after planting.

The white pine weevil (*Pissodes strobi*) does its damage by deforming rather than by killing the trees (*22*). The destruction of the terminal shoot by the larvae of the insect causes the first group of laterals below the injury to turn up and strive for supremacy. This results in decreased height growth and in a forked or crooked stem. Badly weeviled trees may be practically worthless for lumber, as, for example, in the so-called cabbage or pasture pines, the much-forked trunks of which are due to repeated killing of the leader.

Injury is most common when the trees are between 5 and 20 feet tall (*3½*), but may occur at any height. In young stands, and particularly in plantations, as many as 90 per cent of the trees may be affected. The greatest damage is done in stands of pure white pine, where the percentage of weevil injury is much higher than in stands with a considerable mixture of hardwoods. Open-grown stands also suffer severely, since they lack that crowding from the side that is necessary to enable the trees to straighten up and reestablish a single leader. Stands which are dense enough to have 260 or more trees per acre at 50 years of age on average sites, even though weeviled in youth, ordinarily produce material of reasonably good quality.

Weevil damage can be lessened by cutting off the infested leaders in late June or early July before the adults have emerged. These leaders should either be burned or better still placed in an ash can covered with 14-mesh wire screening. The latter will retain the adult weevils but will permit the escape of such parasites of the weevil as may be present. This method of control is too expensive to be carried out on any large scale with natural reproduction. It can, however, be used to advantage with valuable white pine plantations. Cutting of the infested leaders should be begun as soon as the presence of the insect is detected and should be continued each year as long as the leaders can be readily reached.

Other methods of direct control, such as spraying the trees with some repellant, banding them with tanglefoot, and jarring the adult weevils in early spring into a net held at the base of the leader, all appear to be less effective and are also too costly for general use. Parasites help much in keeping the weevil in check, but probably little can be done at present to increase their abundance.

The most effective means of controlling the white pine weevil probably lies in the production of well-stocked, mixed stands. This emphasizes the desirability of letting pure stands of white pine revert to the pine-hardwoods type wherever soil conditions are favorable for the hardwoods. The partial overhead shade afforded by the hardwoods during the first 8 or 10 years in the life of the pine, and the side shade afforded thereafter, will do much to decrease weevil injury. Moreover, in dense stands, such trees as are attacked will have a good opportunity to replace the lost leader and to develop fairly straight stems.

YIELDS

White pine probably produces a larger volume per acre, age for age, than any other species in the Northeast. Measurements of 196 typical fully stocked second-growth stands in New Hampshire are given in Table 18 (*20*).

TABLE 18.—*Volume per acre of fully stocked second-growth stands of northern white pine, New Hampshire; basis, 196 plots*

Age (years)	Volume on—			Age (years)	Volume on—		
	Good sites	Average sites	Poor sites		Good sites	Average sites	Poor sites
	Board feet	*Board feet*	*Board feet*		*Board feet*	*Board feet*	*Board feet*
30	13,900	9,600	5,300	70	69,900	56,100	42,300
40	32,800	23,500	14,200	80	77,850	64,000	50,100
50	49,100	36,600	24,100	90	84,800	70,900	57,000
60	60,200	46,900	33,600	100	91,200	77,000	62,800

The board-foot volumes show the actual mill tally of all trees 5 inches or more in diameter at breastheight. Sixty per cent of the lumber sawed was round-edged and 40 per cent squared; 70 per cent

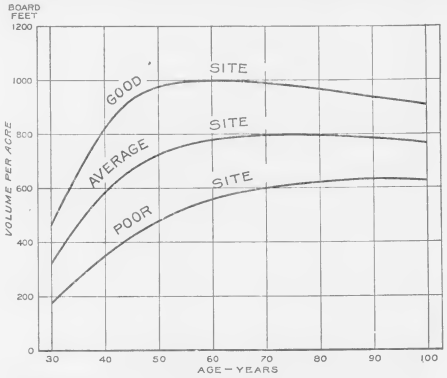

FIGURE 19.—Mean annual growth of fully stocked, even-aged stands of white pine

went into 1-inch boards and 30 per cent into 2⅛-inch plank. The values run somewhat higher than those determined by log scale. Board feet can be converted into cords, which is the unit of measurement often used when pine is cut for pail stock and similar products, on the assumption that there are approximately two cords to every thousand board feet.

The mean annual growth of white pine at different ages is shown in Figure 19. These figures are for unmanaged stands and could undoubtedly be increased by thinnings, which would also produce intermediate yields.

Yield tables have never been prepared on the basis of actual field measurements for the wide variety of mixtures found in the pine-hardwoods type. Theoretical yields have, however, been worked up and are given in Figure 20 (*13*). The average yields for northern

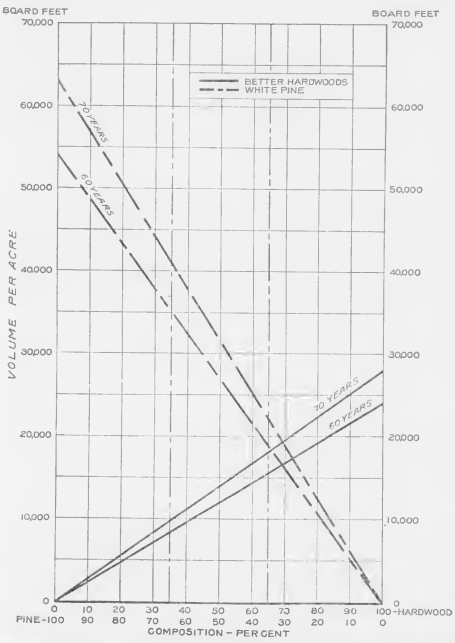

FIGURE 20.—Yield per acre for different combinations of white pine and better hardwoods on the basis of the total area occupied by each. The vertical dash-dot lines indicate the range in composition within which all advantages of the mixtures obtain. (Reproduced by permission from Bulletin No. 8 of the Harvard Forest)

white pine on good and average sites are those indicated in Table 18. Yields for the better hardwoods are taken from average yields of red oak and white ash on good sites as calculated from the study of individual trees and stands. Since all hardwoods tend to approach

either oak or ash in form, and since differences in composition in even-aged mixed hardwood stands appear to cause little variation in yield, it is assumed that these figures will hold for hardwoods in general. They are applicable, however, only to natural stands growing under the most favorable conditions, and probably give a conservative estimate as to what can be expected under management.

From Figure 20 the yield of fully stocked stands of northern white pine and hardwoods in any possible mixture can be readily determined when the percentage of area occupied by each is known. For example, if a given stand at 70 years of age contains 60 per cent pine and 40 per cent hardwoods by area the yield of the former will be 37,800, and of the latter 11,000, or a total of 48,800 board feet. The higher yield of the pine is striking. The chief advantages of mixed stands are believed to be obtained when either group occupies at least 35 per cent of the area.

TRANSITION-HARDWOODS TYPE

The transition-hardwoods type is intermediate in composition between the typical birch, beech, and maple forest of the spruce and northern-hardwoods region and the typical oak forest of the oak region. These and other hardwoods are present in a wide variety of mixture, together with occasional eastern hemlock, northern white pine, Norway pine, and red spruce. Measurements of 40 sample plots showing average composition on sites of good and medium quality in northern Massachusetts are given in Table 19 (*40*).

TABLE 19.—*Composition of average stands in the transition-hardwoods type in northern Massachusetts; basis, 40 plots*

Species	Good sites	Average sites	Species	Good sites	Average sites
	Per cent	*Per cent*		*Per cent*	*Per cent*
Red oak	27	20	Sugar maple	3	6
White ash	15	14	Paper birch	2	8
Red maple	15	12	Beech	2	7
Basswood	9	3	Miscellaneous	6	7
Yellow birch	7	10			
Aspen	7	8	Total	100	100
Chestnut	6	5			

The type occurs chiefly on the better sites, such as moderate slopes, benches, and valley bottoms, with fairly deep, fresh-to-moist soils. Perhaps 90 per cent of the stands are on cut-over land, where they frequently follow one of the pine types. These second-growth stands are usually even aged, with a mixture of seedlings and sprouts. (Pl. 15.)

With its many valuable species and common occurrence in the neighborhood of good markets, the transition-hardwoods type is of much importance both commercially and geographically. In the survey of northern Massachusetts towns already referred to it was found to occupy 26 per cent of the total forest area (*1*). It probably formed a still larger part of the original forest, and is tending to increase in area as white pine is replaced by hardwoods.

METHODS OF CUTTING

Satisfactory natural reproduction in the transition-hardwoods type can ordinarily be obtained either by clear, shelter-wood, or selection cutting. Most of the characteristic species are fairly tolerant of shade in early youth, with the result that an advance growth of seedlings is usually present under mature stands. Clear cutting gives this an opportunity for development and at the same time produces large numbers of sprouts from the stumps of the cut trees.

Shelter-wood cutting is decidedly preferable wherever advance growth is scarce or lacking, since on such areas the new crop, even if satisfactory in numbers, will consist almost wholly of sprouts. As in the pine types, the first cut should take about 40 to 50 per cent of the crown canopy, the remainder being removed as soon as seedling reproduction has become well established. Shelter-wood cutting also has the advantage, where such reproduction is already present, of stimulating its growth and thereby enabling it by the time of the final cutting to reach a sufficient height to compete on more even terms with the stump sprouts.

Selection cutting, or the removal year after year of only the larger trees, gives an opportunity for new growth to start in the openings thus made and can be used to advantage in uneven-aged stands. It is particularly profitable for the small owner who wishes to maintain some merchantable material on his land at all times.

Cleanings of young stands are important, and are usually necessary within three to five years after the complete removal of the mature timber. They should aim to favor the best species, notably red oak and white ash. Where these are abundant, and are freed from competition of less desirable species, they may make up as much as 80 per cent of the new crop. Cleanings should also favor seedlings and thrifty, well-formed individuals. In general, they are similar to those in pine and hardwood stands, except for the fact that pine does not have to be taken into consideration. Except where especially troublesome species, such as red maple, are present in large number, one cleaning should ordinarily be sufficient.

Thinnings are advisable as soon as overcrowding begins, say from 20 years on, wherever there is a market for the material removed. Straight, dominant trees of valuable species should be favored, but not those which are so tall as to be likely to develop into "wolf" trees. Frequent light thinnings, at intervals of from 5 to 10 years, are better than infrequent heavy ones.

The slash left after logging decays so rapidly and interferes so little with reproduction that no special disposal is necessary. No stock should be allowed to graze on cut-over lands, since both cattle and sheep are likely to cause serious injury to all species of hardwoods.

YIELDS

The theoretical yield of red oak and white ash at 60 and 70 years of age has already been indicated in Figure 20. Actual measurements (*40*) of 40 sample plots in fully stocked, even-aged stands in which the better hardwoods (chiefly red oak, white ash, sugar maple, and yellow birch) were present in a wide variety of mixtures established cordwood and lumber yields as given in Table 20.

TABLE 20.—*Yield per acre in fully stocked, even-aged stands in the transition-hardwoods type; basis, 40 plots*

Age (years)	Volume per acre on—					
	Good sites			Average sites		
	Cordwood [1]	Saw logs plus cordwood [2]		Cordwood [1]	Saw logs plus cordwood [2]	
	Cords	*Board feet*	*Cords*	*Cords*	*Board feet*	*Cords*
30	29.8			20.4		
40	39.6	4,720	9.2	29.5	1,920	9.1
50	48.0	10,310	8.3	36.0	4,780	12.3
60	55.5	15,620	5.6	41.1	8,660	10.2
70	62.8	19,830	5.3	45.6	12,710	7.1
80	69.5	23,400	5.3	49.8	15,380	6.1

[1] Includes all trees 2 inches and over in diameter.
[2] Includes all trees 7 inches and over in diameter.

Cord volumes were determined with a volume table for red maple, which was found by actual test to be equally applicable to other hardwoods of the same diameter and height. The solid contents of a stacked cord varied from about 67 cubic feet with the smaller trees to about 90 cubic feet with the larger.

Board-foot volumes were computed by the international rule, which gives slightly lower values than those found by mill-scale studies in the same locality. Hardwoods are usually sawed through

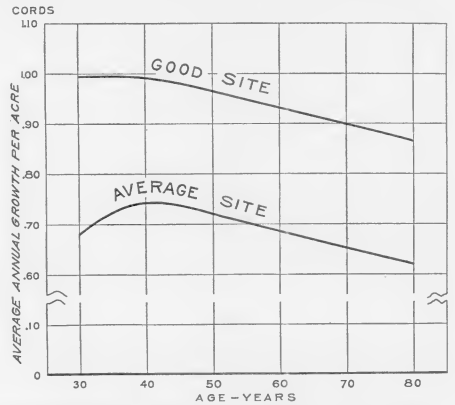

FIGURE 21.—Mean annual growth in cords of fully stocked, even-aged stands of better hardwoods for all trees 2 inches and over in diameter at breastheight

and through into round-edged lumber. Any tree is considered merchantable which will give an 8-foot log out of which a board with a minimum width of 5 inches can be sawed. The "additional cords" were determined by finding the total contents of the trees in cords and subtracting from this figure the cord equivalent of the board-foot contents, on the assumption that there were 6 board feet to the

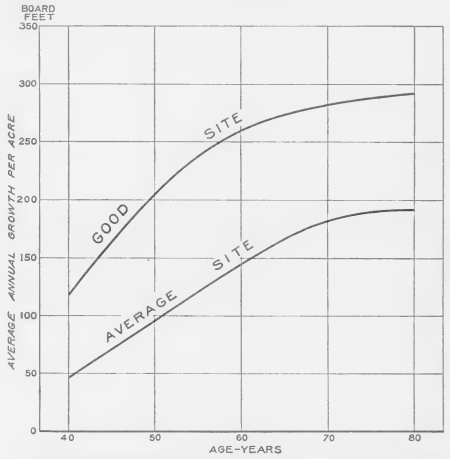

FIGURE 22.—Mean annual growth in board feet of fully stocked, even-aged stands of better hardwoods for all trees 7 inches and over in diameter at breastheight

cubic foot and 65 cubic feet to the cord. Material in trees from 2 to 5 inches in diameter, which can also be utilized where there is a good market for fuel, varies from 18.3 cords at 40 years of age to 3.9 cords at 80 years on good sites, with slightly smaller yields on average sites.

Average annual growth per acre is shown in Figures 21 and 22. The comparatively uniform growth of nearly 1 cord per acre per year on good sites and of nearly 0.7 of a cord on average sites between 30 and 80 years of age is very striking. Better results could undoubtedly be obtained with thinnings.

GRAY BIRCH TYPE

The gray birch type occurs extensively throughout the white pine region and is also common in the sprout-hardwoods region. Gray birch is the characteristic and predominant species, usually in mixture with more or less red maple and aspen. Other hardwoods and occasionally pine occur scatteringly in wide variety. The average distribution of species on eight sample plots in northern Massachusetts is given in Table 21 (*40*).

TABLE 21.—*Distribution of species in the gray birch type of the Northeast; average of eight plots in northern Massachusetts*

Species	Distribution	Species	Distribution
	Per cent		*Per cent*
Gray birch	38	Sugar maple	2
Red maple	24	Red oak	2
Aspen	15	Miscellaneous	12
Yellow birch	4		
Paper birch	3	Total	100

The type is found on nearly all sites from dry to wet, and from sterile to fertile. Gray birch and aspen are so intolerant of shade that they seldom come in under the cover of existing stands. Their light seeds and common occurrence, however, enable them to reproduce abundantly in the form of even-aged stands on areas that have been cleared by cultivation, fire, or logging. The type is particularly characteristic of old fields, but also frequently follows cutting in the white pine type. The Harvard Forest's survey of northern Massachusetts towns showed this to be true in 25 per cent of the stands examined.

This same survey showed that 17 per cent of the total forest area in that part of the region was occupied by the gray birch type. Locally it is often still more abundant. In spite of its large area, however, it is of comparatively little commercial importance because of the small size and inferior quality of the short-lived gray birch and aspen. If fire is kept out, it is also a distinctly temporary type, since the light foliage and comparatively open crowns of these species permit white pine and the more valuable hardwoods to seed in and eventually to replace them.

The gray birch type is, therefore, constantly coming in on certain areas and being crowded out on others. It has undoubtedly increased in abundance during the last few decades and is probably still gaining ground. This is due in large part to the fact that gray birch, aspen, and red maple have been cut far less heavily than their more valuable associates, and have thus had every opportunity to spread. Their more rapid early height growth also gives them a distinct advantage over their competitors in uncleaned stands.

METHODS OF CUTTING

The chief object of cutting in the gray birch type is not to perpetuate it but to hasten its reversion to a forest of more valuable species. This can be done, wherever gray birch, red maple, and aspen can be marketed for fuel, by clear cutting as soon as the stand reaches merchantable size. Complete removal of these inferior species is ordinarily sufficient to enable the advance reproduction of white pine and of the more valuable hardwoods, such as red oak, white ash, and yellow birch, to take possession of the area. Subsequent cleanings may, however, be needed if the advance growth has not reached a sufficient height to hold its own with the vigorous sprouts which will spring from the stumps of the cut trees.

In areas where the gray birch type is not being replaced naturally by some other type, planting, particularly of white or Norway pine, may be profitable. This can best be done under the shade of the existing stand, which should be removed from three to eight years later, after the pine has become thoroughly established. If the pine is allowed to reach a height of about 4 feet before the stand is removed, subsequent cleaning will seldom be necessary.

Slash resulting from the cutting of gray birch and its associates is ordinarily so light and decays so readily that no disposal of it is necessary.

YIELDS

Measurements of eight sample plots in northern Masachusetts containing fully stocked, even-aged stands of inferior hardwoods (*40*) give the yields presented in Table 22.

TABLE 22.—*Yield per acre in fully stocked, even-aged stands of the inferior hardwoods of the gray-birch type in northern Massachusetts; basis, eight plots.*

Age	Volume per acre on good site
	Cords
20 years	18.1
25 years	20.5
30 years	20.6

Soil conditions were slightly better than average for this type. All trees 2 inches or over in diameter at breastheight are included. Cord volume was determined in the same way as for the better hardwoods. (Table 18.) Since gray birch deteriorates rapidly after it is 30 years old, there may be an actual decrease in yield after that age, depending on the amount of gray birch in the stand.

The mean annual growth drops from nine-tenths of a cord per acre per year at 20 years of age to two-thirds of a cord at 30 years.

OAK REGION

The oak region is characterized by a varying mixture of oaks, hickories, maples, and birches, with some yellow poplar and other hardwoods on the better sites. Chestnut was formerly abundant, but nearly all trees of merchantable size have now been killed by the blight. Repeated cuttings and fires have been responsible for the replacement of hemlock, which was also much more common in the original forest, by the more aggressive hardwoods. White pine is relatively scarce in spite of the large area of abandoned farm lands.

The predominant types are oak, gray birch, and hardwood-swamp. In addition, the white pine type and the pine-hardwoods type are found in the oak region, but they occupy a much smaller area than in the white pine region. The mixed-hardwoods type of the Allegheny hardwoods, pine, and hemlock region also occurs here on the better sites.

The region occupies most of Rhode Island, Connecticut, northern Long Island, the Hudson River Valley, the valleys of northern and western New Jersey, eastern and southwestern Pennsylvania, exclusive of the Poconos, and a belt along the south shore of Lake Ontario. The elevations are mostly low and the topography flat or slightly rolling. Like the white-pine region, the oak region is thickly settled, has good markets and good transportation facilities, and maintains its forests largely in the form of farm wood lots.

OAK TYPE

The oak type is both geographically and commercially of outstanding importance throughout the oak region. (Pl. 16, A.) Red, white, chestnut, black, and scarlet oak usually constitute from 50 to 90 per cent of the stand. Numerous other hardwoods, such as red and sugar maple, shagbark, pignut, and mockernut hickory, sweet birch, white ash, black cherry, beech, and yellow poplar, are present in widely varying numbers. Minor species, often prominent in young but seldom in mature stands, include dogwood, hophornbeam, blue beech, sassafras, gray birch, and aspen. Chestnut, formerly so abundant as to receive recognition as a distinct type, has now been practically exterminated in merchantable size by the blight (*Endothia parasitica*) and is being replaced chiefly by oak (*28*, *29*). Hemlock was in all probability common in the original forest in the northern part of the region, but has been greatly reduced in numbers by repeated clear-cutting and surface fires.

The oak type occurs on well-drained sites on all aspects and soils. Its composition, however, varies materially on different sites and in different parts of the region. Thus, chestnut oak is so much more abundant on the poorer sites as to form at times almost pure stands. On such sites it is also frequently associated with pitch pine, particularly in northwestern New Jersey and eastern Pennsylvania, where the chestnut oak-pitch pine combination is so characteristic as sometimes to be classified as a separate type. White ash, black cherry, and yellow poplar, on the other hand, are much more abundant on the better sites. Hickory is a fairly constant associate of the oaks on all sites, especially in the southern part of the region.

The type occurs chiefly in the form of farm wood lots in well-settled districts with good markets. The original forests were long ago replaced by roughly even-aged second-growth stands, which have also come in extensively on abandoned farms. These second-growth stands have been cut both frequently and heavily, and have also suffered badly from fire. As a result, they are for the most part moderately well-stocked and are composed largely of sprouts, many of them poorly formed, defective, or of inferior species. Production is therefore seldom equal to that of which the site is capable.

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ADVANCE GROWTH IN HARDWOOD STANDS

A, Advance reproduction of hardwoods, chiefly white ash, in the transition-hardwoods type (Harvard Forest). Reproduction of pine is exceedingly difficult in a stand of this character. B, A fairly mature stand in the transition-hardwoods type, Merrimack County, N. H. Note the abundant advance growth of hardwoods ready to take possession of the area when the stand is cut. C, A 15-year-old stand of second-growth sugar maple, white ash, and basswood in the Harvard Forest, consisting entirely of advance growth which came in under pure white pine and has been weeded once to favor the more valuable species and individuals. This is a striking example of the tendency for the white pine type to be replaced naturally by transition hardwoods.

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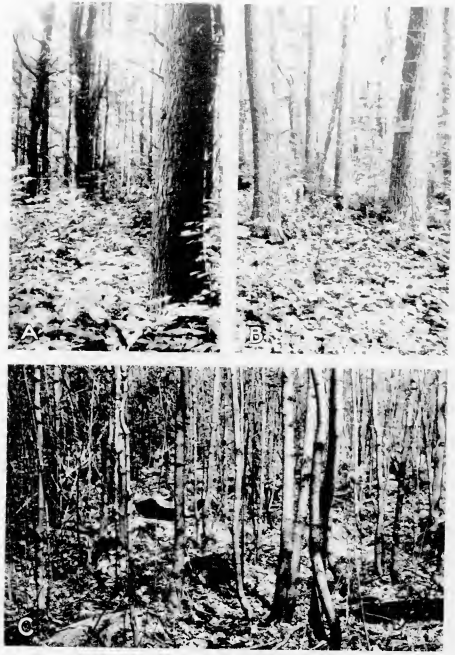

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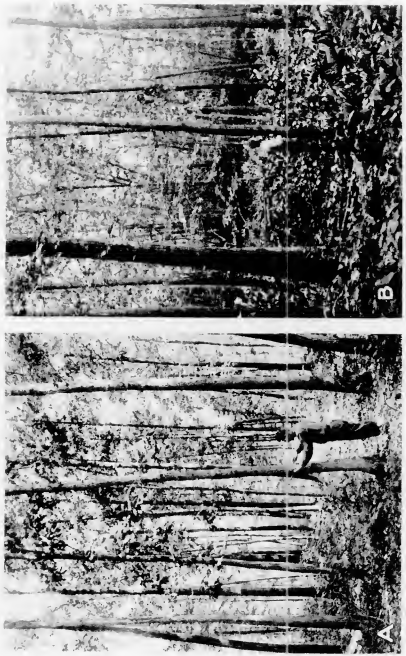

THE OAK TYPE

A, A 35-year-old stand in the oak type in New Jersey after an improvement cutting (Photograph by courtesy of the N. J. Dept. Conservation and Development); B, a rather heavy thinning in an overstocked stand in the oak type, Middlesex County, Conn. (P-46565)

NATURAL REPRODUCTION

Although most of the trees characteristic of the oak type, except maple and birch, require a large amount of light for their best development, they are able to start and to persist for a number of years under some overhead shade. Reproduction of both seedlings and sprouts is, therefore, usually abundant in stands which are naturally rather open or which have been opened up by thinnings or other cutting.

Information on the composition and development of the reproduction under fairly typical conditions is afforded by intensive studies by the Yale School of Forestry in southern Connecticut (*30*). The stands studied consisted of about 75 per cent oak and 25 per cent other hardwoods (chestnut, formerly abundant, being eliminated). Thinnings and salvage cuttings for the removal of dead chestnut had been made over most of the area in 1902, 1905, 1908, 1910, and 1913, and over smaller portions in other years. In the winter of 1921 the remainder of the stand was cut clear at about 75 years of age. The condition of the reproduction on the area four years later is indicated in Tables 23 and 24.

TABLE 23.—*Reproduction in the oak type four years after the clear cutting of a 75-year-old stand*

Species	Good sites		Average sites		Poor sites	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Oaks	3,956	35	5,331	62	3,017	70
Other hardwoods	7,443	65	3,343	38	1,275	30
Total	11,399	100	8,674	100	4,292	100

TABLE 24.—*Distribution of oaks in 4-year-old reproduction following clear cutting in the oak type*

Species	Good site	Average site	Poor site
	Per cent	*Per cent*	*Per cent*
Red oak	13	8	6
Black oak	10	6	8
Scarlet oak	26	14	11
Chestnut oak	6	53	59
White oak	45	19	16
Total	100	100	100

The much greater proportion of chestnut oak and the smaller proportion of white oak on the poorer sites is very striking. Red oak often constitutes a much larger part of the stand, particularly on good and average sites, than on the areas covered by this study. "Other hardwoods" included 22 species. Many of these, however, such as dogwood, blue beech, hophornbeam, sassafras, and serviceberry, are of minor importance and seldom reach large size. Red maple is the most common single species, constituting 19, 20, and 16 per cent, respectively, on the three sites. Chestnut reproduction was not counted because of the certainty that it would soon be killed

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back by the blight. Woody shrubs (viburnum, hazelnut, and witch-hazel) ran from 5,300 per acre on the good sites to 780 on poor sites. There is every indication that the oaks will again predominate in the mature stand, especially if given some relief from red maple competition.

The relative quantities of reproduction coming in before and after the clear cutting in 1921 are shown in Figure 23. That before cutting is designated as "advance growth," that after cutting as "younger reproduction." The figure brings out clearly the predominance of the younger reproduction, particularly with other hardwoods than oak. Much advance growth that started after the various thinnings undoubtedly died under the cover of the remaining stand prior to the final cutting. On good sites the advance growth ranged from 7 to 22 years in age and from 5 to 28 feet in height,

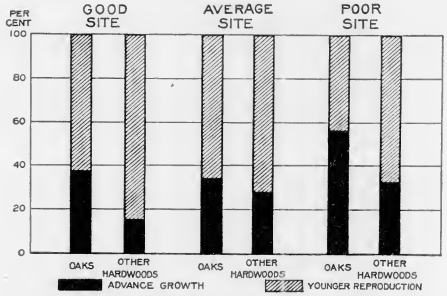

FIGURE 23.—Relative quantities of reproduction coming in before and after the final cutting in second-growth hardwood stands in Connecticut

while the younger reproduction ranged from 1 to 4 years in age and from 2 to 14 feet in height.

Figure 24 shows the relative quantities of both advance growth and younger reproduction in the form of seedlings, seedling sprouts, and sprouts. "Seedling sprouts" are those from stumps 2 inches or less at the ground line. The large proportion of seedlings and seedling sprouts—the more desirable elements in the stand—is particularly worthy of note. Sprouts are less abundant probably because they are unable to endure much overhead shade and because large stumps often fail to produce sprouts.

From 50 to 90 per cent of the seedlings and seedling sprouts and from 80 to 100 per cent of the sprouts were in a free position with apparently ample opportunity for growth. The much larger proportion of sprouts occupying a free position is undoubtedly due to their more rapid height growth in early youth. Even in the younger

reproduction, however, there are enough seedlings and seedling sprouts to form an important part of the mature stand if they are able to escape subsequent suppression.

Studies in older stands indicate that seedling sprouts usually reach the same height as sprouts at between 20 and 30 years of age, and seedlings at about 40 years. Thereafter, the rate of growth of the different forms is nearly the same, with perhaps a slight advantage in favor of the seedlings. These facts indicate that seedlings coming in after the final cutting can be counted on to form an important part of the next stand, provided they have sufficient growing space to permit their unhampered development.

Most of the advance growth consisted of well-formed young trees. Poorly formed individuals were usually of sprout origin. Less than 6 per cent of the oaks were flat topped, and these showed the same

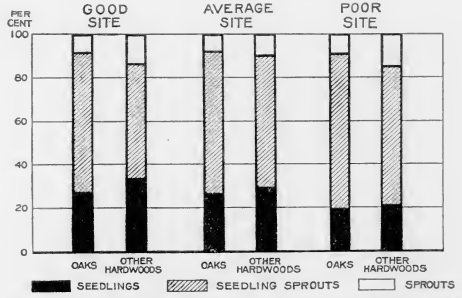

FIGURE 24.—Relative quantities of reproduction in the form of seedlings, seedling sprouts, and sprouts in second-growth hardwood stands in Connecticut

rate of growth after cutting as did those with normal or spreading crowns. But since the overhead cover on these particular areas was not dense, this growth does not necessarily imply an ability on the part of hardwoods to recover quickly from the effects of heavy and prolonged shading.

Briefly summarized, the results of these studies indicate that moderately open stands in the oak type will ordinarily be followed after clear cutting by ample reproduction of desirable species and individuals. In spite of the larger size of the advance growth and the more rapid development at first of the sprouts and seedling sprouts originating after the final cutting, there is a marked tendency for these early differences to disappear and for the dominant trees to form a practically even-aged stand of fairly uniform height. It is estimated that after 50 years of age the composition of untreated stands will be approximately as in Table 25.

TABLE 25.—*Estimated composition of untreated stands in the oak type after reaching 50 years of age*

Type of forest growth	Good site	Average site	Poor site
	Per cent	*Per cent*	*Per cent*
Oak, well formed, free seedlings and seedling sprouts	50	55	55
Other hardwoods, well formed, free seedlings and seedling sprouts	15	10	5
Sprouts, all species, and poorly formed seedlings and seedling sprouts	35	35	40

Similar results may reasonably be expected from other parts of the region, although of course with considerable variation in the relative quantities of the different species present.

METHODS OF CUTTING

Where fire and grazing are excluded, the oak type reproduces itself so readily that satisfactory results can often be obtained by any one of several methods of cutting. Consequently the choice between removing the timber in one or two cuttings, or in a series of light, successive cuttings, depends largely on whether the stand is even aged and on the wishes of the owner. In general, cuttings aimed at improving the composition and quality of the stand are fully as important as those aimed primarily at obtaining reproduction.

Clear cutting of all merchantable material to as small a diameter as possible is usually advisable in mature, even-aged stands in the oak type wherever natural reproduction is already present. This reproduction, with the additional sprouts and seedlings which are fairly sure to follow the cutting, will form the basis for a new stand and will take prompt advantage of the increased light and soil moisture made available by the removal of the older trees. The best sprouts will be produced from low stumps with smooth surfaces cut at a sufficient angle to let the water drain off. Care should be taken not to strip the bark from the stump. Logging should be done during the period of vegetative rest between late fall and early spring, since summer-cut stumps are apt to produce weak sprouts which are too tender to withstand the first frosts. Care should be taken in logging not to injure the advance growth already on the ground.

In the occasional instances where advance growth is not present, clear cutting is less satisfactory unless accompanied by planting. The absence of seedlings, the considerable distances between the clumps of sprouts that will spring from the stumps of cut trees, and the probable failure of the larger stumps to sprout at all, are likely to result in partially stocked stands with too large a proportion of sprouts, many of them poorly formed or defective. On such areas the stand can well be removed in two cuttings by the shelter-wood method. The first cutting should leave about half of the stand in the form of evenly distributed, thrifty trees of desirable species capable of bearing full crops of seed. These can then be cut clear after the reproduction is well established, say in four to eight years. If the cutting is done too soon, it will not give the seedlings so good a

chance to hold their own with the less desirable sprouts; while if it is delayed too long, the advance growth will be retarded wherever it occurs under moderately heavy shade and given too much of a start in openings. Logging by the shelter-wood method may cost from $0.50 to $1 per thousand board feet more than clear cutting. On the other hand, aside from the fact that it affords much greater assurance of a satisfactory new crop, this additional cost may be more than offset by the greater value per thousand board feet or per cord of the timber removed, and by the increased growth and consequently increased value of the timber left for the second cut.

An alternative to shelter-wood cutting where advance growth is not present is to cut the stand clear and plant among the stumps 100 to 200 seedlings of the species which it is desired to favor, to fill in the open places that will not be occupied by sprouts. This method would probably not cost any more than shelter-wood cutting, perhaps less, and would give somewhat more control over the composition of the new stand.

In uneven-aged stands, light cuttings which remove only a few of the larger trees at any one time are likely to be most satisfactory. Cuttings of this sort are particularly suited to the needs of the small wood-lot owner who wishes to maintain a constant supply of timber for his own use and for the general market. The spaces left by the trees removed are filled promptly by young seedlings and sprouts, which gradually take their place in the main stand. The opportunity for development of the new growth is better if the cutting is by small groups rather than by individual trees. Selection cuttings of this sort to stimulate reproduction can often be combined to advantage with the improvement cuttings described in succeeding paragraphs.

The quality of young stands can usually be improved by cleanings. (Pl. 16, B.) These should cut back poorly formed and defective trees of all species; occasional dominants of inferior species, such as red maple, gray birch, or aspen, which are overtopping oak, white ash, yellow poplar, black cherry, or other desirable species; and dominant sprouts which are overtopping more desirable seedlings or seedling sprouts. Scarlet oak should be discriminated against because of its relatively inferior wood and its tendency to heart rot.

Cleaning should be deferred until three to five years after the final cutting in order to show up more clearly the trees which should be favored and to give then a better opportunity to retain a dominant position after they have once been freed. A second cleaning may occasionally be necessary but will require less cutting than the first. In any event, cleaning will be less expensive than in the white pine type, because the various hardwoods compete on more even terms than do pine and hardwoods. The cost should not exceed $1 to $4 per acre.

Where this cost does not appear to be justified by the probable increase in returns from the improved stand, treatment can be delayed until the trees to be removed are large enough to pay for the cost of logging (*30*). Under good market conditions, this will ordinarily be when they are between 20 and 30 years of age. The same classes of trees should be removed as in cleanings, with the object

of favoring the better species and individual trees and of preventing the development of "wolf" trees. While an improvement cutting of this sort does not free the more desirable elements in the stand at as early an age as does a cleaning, its results are as a rule reasonably satisfactory. Cleanings are particularly essential where the lack of any market for cordwood precludes improvement cuttings until considerably later in the life of the stand.

By the time they are 20 to 30 years old, fully stocked stands are also usually in need of thinning, in order to prevent a falling off in the rate of growth. Where this is the case and market conditions permit, removal of undesirable trees of the sorts already specified should be supplemented by the removal of enough of the medium-sized and larger trees to give the thrifty, dominant ones which are retained ample room for development. Ordinarily, sufficient space should be left between the crowns of adjacent trees so that they will come together again in about 5 years. Subsequent thinnings can be made at intervals of 5 to 10 years and can be increasingly heavy as the stand becomes older. After the trees have reached the seed-bearing age, any opening up of the stand is apt to be followed by reproduction, so that a heavy thinning in a stand approaching maturity may virtually take the place of the first cutting in the shelter-wood method. Where frequent light thinnings are not practicable, a heavy thinning at 35 to 40 years of age is desirable.

Thinnings usually remove from 20 to 40 per cent of the total volume of the stand. On the basis of total number of trees the proportion removed varies widely with the density, but usually runs considerably higher. Since the trees taken are mostly in the smaller-size classes, the result is to raise the average diameter of the stand. Table 26 shows trees of the different crown classes taken in a typical thinning in a 46-year-old stand on a poor site in Connecticut (*19*), where 28 per cent of the total volume was removed.

TABLE 26.—*Summary of a thinning operation in a 46-year-old stand on a poor site in the oak type, Connecticut—volume removed, 28 per cent*

Crown class	Original stand per acre	Trees removed per acre	
	Number	*Number*	*Per cent*
Dominant	200	16	8
Codominant	100	16	16
Intermediate	136	68	50
Overtopped	156	140	90
Dead	132	132	100
Entire stand	724	372	51

Experiments in New York State (*41*) indicate that thinnings and reproduction cuttings may reduce by 30 to 50 years the period required by red oak, white oak, and chestnut oak to obtain merchantable diameters of 12 inches and more.

The results of thinnings in even-aged, fully stocked, crowded, but thrifty stands in New Jersey (*2*) are given in Table 27.

TABLE 27.—*Results of thinnings in even-aged, fully stocked, crowded, but thrifty oak stands, New Jersey, as shown by trees 2 inches and more in diameter*

Age of stand (years)	Degree of thinning	Stand[1]—		Average diameter of trees—		Volume per acre—	
		Before thinning	After thinning	Before thinning	After thinning	Before thinning	After thinning
		Number	*Number*	*Inches*	*Inches*	*Cords*	*Cords*
25	Light	800	450	3.5	4.0	18	14
25	Medium	800	375	3.5	4.5	18	12
25	Heavy	800	300	3.5	5.0	18	10
35	Light	700	350	4.5	5.0	25	20
35	Medium	700	300	4.5	5.5	25	17
35	Heavy	700	200	4.5	6.0	25	15
50	Light	600	275	5.0	6.0	30	24
50	Medium	600	250	5.0	6.5	30	21
50	Heavy	600	200	5.0	7.0	30	18

[1] The number of trees per acre has been evened off in all cases.

Many farmers can use thinnings as a means of providing their winter's supply of fuel, thus improving the wood lot at practically no cost except for the labor involved. Since the oak type occurs chiefly in well-settled districts in proximity to good markets, thinnings can often be made to yield a substantial cash profit. For example (*2*), the best offer one farmer in northern New Jersey could get from lumbermen was $25 per acre for all of the standing timber on a 30-acre wood lot of young mixed hardwoods. After consulting the State forester, he decided to thin the stand and to do his own cutting. By removing only trees of inferior form or species and those unduly crowding others, he made a net profit of $35 per acre and had left instead of stump land a stand of thrifty young timber which he valued at $15 per acre.

Another New Jersey example is that of a community church which made a thinning in a 20-acre wood lot of 27-year-old mixed hardwoods that were still thrifty but becoming so badly crowded that growth was slowing up. Cordwood, fence posts, and bean poles were cut at a net profit of $37 per acre, leaving a full stand of thrifty, fast-growing, immature trees for further development. Moreover, the value of the final crop will probably be more than doubled by this thinning, and the crop will mature much sooner.

The increased growth resulting from thinning is illustrated by the comparison in Table 28 of two similar plots about 25 years of age and containing about 65 per cent oak, one of which was thinned and the other left unthinned. The more rapid rate of growth of the thinned stand, its greater total volume, and the concentration of this volume in thrifty trees of desirable species, all indicate its superiority over the unthinned stand. This is emphasized by the fact that the thinning was a light one and that 36 of the trees which had been left for further growth were killed by careless brush burning.

TABLE 28.—*Comparison of thinned and unthinned 25-year-old stands in the oak type (oak 65 per cent) five years after thinning*

Treatment	Original stand			Removed in thinning		Stand five years after thinning			Average annual growth
	Trees	Average diameter	Volume	Trees	Volume	Trees	Average diameter	Volume	
	Number	*Inches*	*Cords*	*Number*	*Cords*	*Number*	*Inches*	*Cords*	*Cords*
Thinned	872	3.7	19.5	420	3.6	416	5.4	21.5	1.1
Unthinned	780	3.7	16.2	.....	.....	632	4.4	19.8	0.7

In the irregular stands which have resulted from the repeated culling of the better species and individuals, a combination of thinnings, improvement cuttings, and reproduction cuttings is usually needed. All dead, dying, poorly formed, large-crowned, and defective trees should come out, thus stimulating new reproduction and the development of young trees already on the ground; while the occasional dense stands of saplings and small poles should be thinned out to prevent stagnation in growth. Two or three cuttings are usually sufficient to bring even badly run-down stands into fairly good condition.

Recent sudies by the Yale School of Forestry (*31*) indicate that in southern New England, at least, hemlock gives larger yields than hardwoods and may be well worth encouraging. Wherever hemlock is present in mature stands, this can be done by leaving 1 to 10 seed trees per acre at the time of the final cutting. Good reproduction will often start from these, and the young hemlocks, which are very persistent even under a fairly dense overhead shade, can later be helped along by favoring them in cleanings, improvement cuttings, and thinnings.

On poor sites it may be worth while to convert the oak type into a coniferous or mixed type, by planting white pine or Norway pine. These species give larger yields and, in such plantations as have been made, indicate their ability to thrive on soils where oak and other hardwoods do poorly. The conversion should be effected by clear cutting the existing stand and as much advance growth as possible, setting out vigorous 3 or 4 year old pine transplants, particularly in openings, and later cutting back the competing hardwoods wherever neecssary until the pines are sufficiently established to take care of themselves. Two cleanings will often be necessary. The total expense will probably run from about $5 per acre when only 200 to 300 pines are planted to $20 per acre when 1,000 or 1,200 trees are used. The smaller number will result in a mixed stand of conifers and hardwoods in which the conifers will occupy a prominent place if properly favored by cleanings.

Utilization in the oak type, both in final cuttings and thinnings, is usually so close as to leave only a small amount of slash, which decays rapidly and seldom interferes with natural reproduction. No special efforts at disposal are necessary, therefore.

Cattle, horses, and sheep do much injury to oak and other hardwoods, and should be kept out of stands of all ages, except on areas where it is particularly desired to favor hemlock or pine. Here, grazing will give the conifers a much better chance for development, although at the same time it is pretty sure to result in some loss from trampling. This is likely to be more serious in plantations where only a limited number of trees is set out than on areas where natural reproduction has come in abundantly.

YIELDS

Measurements of a large number of fully stocked, even-aged stands in the oak type in Connecticut (*19*) indicated the average yields presented in Table 29.

TABLE 29.—*Yields in fully stocked, even-aged stands in the oak type, Connecticut*[1]

Age (years)	Height, dominant trees	Average diameter	Stand per acre	Volume per acre[2]	
	Feet	*Inches*	*Number*	*Cords*	*Board feet*
GOOD SITES					
30	57	5.5	575	30	1,900
40	68	7.2	405	40	5,500
50	75	8.7	310	48	9,200
60	80	10.0	260	53	12,700
70	84	11.1	220	58	15,900
75	86	11.6	210	60	17,100
AVERAGE SITES					
30	47	4.6	675	24	600
40	57	6.0	485	32	2,500
50	64	7.1	390	38	5,100
60	68	8.1	325	43	8,000
70	72	8.9	280	47	10,700
75	73	9.4	255	48	11,900
POOR SITES					
30	37	3.7	880	17	
40	46	4.7	650	24	1,200
50	52	5.5	515	29	2,700
60	56	6.2	430	32	4,700
70	60	6.8	275	35	6,500
75	61	7.1	345	36	7,400

[1] Figures are for trees 2 inches d. b. h., and more except as noted.
[2] Board foot volumes are for trees 9 inches d. b. h. and more.

The volume per acre in cords, which includes all trees 2 inches and over in diameter at breastheight to a top diameter of 2 inches outside bark, was first determined in cubic feet, which were changed to cords by the use of a converting factor varying from about 75 to 95 cubic feet per stacked cord, depending on the size of the average tree.

Since no figures of yield in board feet are available for the oak type, those for the chestnut type are given, with a deduction of 33⅓ per cent to allow for the considerably higher yield of the chestnut. The necessity of making so liberal a discount, which is probably none too much, gives some idea of the decreased production of stands in the sprout-hardwoods region resulting from the loss of the chestnut. Volumes of individual trees were scaled by the international rule, with a deduction of 10 per cent to allow for the wide kerf cut by the circular saw of the average portable sawmill. No allowance was made for defect. In addition to the lumber, the original chestnut stands contained from 20 to 30 cords in the form of tops and of trees too small for lumber.

The average annual growth of fully stocked stands in the oak type in Connecticut is shown in Figure 25 on the following page.

HARDWOOD-SWAMP TYPE

The hardwood-swamp type, although nowhere covering a large area, deserves mention on account of its extensive distribution throughout the Northeast. It is not distinctively characteristic of

any one forest region, but is described under the oak region because of its predominance there.

Red maple is everywhere the most characteristic species. Black ash, white ash, American elm, and willows are usually present in varying amounts. Yellow birch, tamarack, and spruce are more or less common toward the north; and black gum, sycamore, swamp

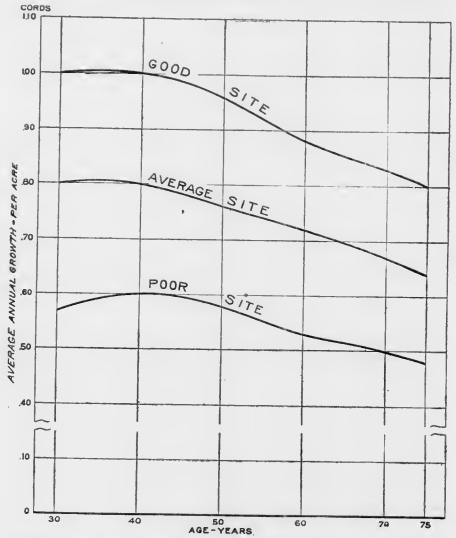

FIGURE 25.—Mean annual growth of fully stocked, even-aged stands in the oak type, Connecticut

white oak, pin oak, yellow poplar, silver maple, and river birch toward the south.

The type occupies low, wet, poorly drained sites. Although decidedly of secondary importance, it is occasionally valuable locally as a source of fuel. Clear cutting is necessary because of the danger of windfall. Satisfactory restocking usually takes place from seedlings already on the ground and from the vigorous sprouts, particularly of red maple, which follow cutting. The slash is light, decays readily, and requires no special treatment.

OTHER TYPES

The following types are discussed at length under the region indicated, and the suggestions for handling them given there apply equally well in the oak region: White pine type, white pine and hardwoods type, and gray birch type, white pine region; and mixed-hardwoods type, Allegheny hardwoods-pine-hemlock region.

ALLEGHENY HARDWOODS-PINE-HEMLOCK REGION

The Allegheny hardwoods-pine-hemlock region is essentially a transition region. It contains representatives of nearly all of the hardwoods found in both the spruce and northern hardwoods region and in the oak region, with a larger representation of such species as black cherry, black walnut, and cucumber magnolia. There is also more northern white pine and eastern hemlock than in either of the two other regions, although the amount of pine is now much less than in the original forest. The principal types are northern hardwoods, mixed hardwoods, and pine and hemlock.

The region occupies the hills of northern New Jersey and south-central and southwestern New York, and the high plateau of northern and central Pennsylvania. In New York the forest occurs largely in the form of farm wood lots, while in New Jersey and Pennsylvania there are more extensive areas of wild land. Transportation facilities are for the most part good, but the markets for small-size material are somewhat uncertain and fluctuating.

MIXED-HARDWOODS TYPE

The mixed-hardwoods type of the Allegheny region consists of a widely varying mixture of the species characteristic both of the transition-hardwoods type of the white pine region and of the oak type of the oak region. Oaks, hickories, maples, birches, beech, white ash, basswood, black cherry, and yellow poplar usually constitute the bulk of the stand. Chestnut, formerly abundant, has been virtually eliminated by the blight. White pine and hemlock are frequently common. There is also a fair sprinking of hardwoods not particularly typical of the Northeast, such as black walnut, cucumber magnolia, bur oak, and bigleaf shagbark hickory.

The type covers a large area and is of considerable commercial importance. It occurs chiefly in northern New Jersey, southern New York, and northern and central Pennsylvania, where it is found in the agricultural valleys and foothills, but seldom extends far into the mountains. Because of repeated culling and grazing, it is for the most part in rather poor condition, with comparatively open stands of inferior trees which are not making full use of the productive capacity of the site.

METHODS OF CUTTING

The mixed-hardwoods type so closely resembles the oak type in its reproduction and development that it can be handled in practically the same way. Where adequate advance growth is present, clear cutting is advisable. (Pl. 17.) Natural reproduction is, how-

ever, less abundant than in the oak type because of the greater prevalence of grazing. Where it is scarce or lacking, the exclusion of stock will ordinarily result in a few years in the establishment of a good crop of seedlings, provided the stand is open enough to admit considerable light. In dense stands, removal of some of the trees by a shelter-wood cutting or by successive selective cuttings, preferably in small groups, will also be necessary to stimulate reproduction. These successive cuttings may be so light as to maintain a continuous growth of timber from which merchantable material may be removed in small quantities every year or at least every few years. This selection system of logging is particularly adapted to uneven-aged stands and to farm wood lots.

The composition and quality of young stands can be improved by a cleaning, which should be made from three to five years after the final cutting. As in the oak type, the less desirable species, particularly red maple, the poorer trees of all species, and the sprouts which are overtopping seedlings or seedling sprouts, should be cut back to favor the better elements in the stand. As soon as the trees are large enough to have a value as cordwood, usually between 20 and 30 years of age, a similar improvement cutting is desirable. This may either be in place of, or preferably in addition to, an earlier cleaning.

Thinnings to maintain a high rate of growth are also important as soon as overcrowding begins. These should aim to leave a uniform stand of thrifty, well-formed trees of desirable species with ample growing space. Because of the generally favorable market conditions, they can usually be made without loss, and often at a substantial profit. (Pl. 18.)

An experiment by the department of forestry of the New York State College of Agriculture illustrates the advantages of thinning (*23*). Three plots were laid out in 1914 in an even-aged, 25-year-old stand made up of both seedlings and sprouts. A wide variety of hardwoods was present, including sugar maple, red maple, basswood, hickory, elm, red oak, white oak, white ash, yellow poplar, butternut, and black cherry. The plots were so selected as to be as similar as possible in composition, age, height, and density. One plot was heavily thinned, a second lightly thinned, and the third left unthinned as a check. Five and ten years later the plots were remeasured; the results are given in Table 30. It is evident from these figures that both diameter growth and volume growth increased in proportion to the severity of the thinning. The increase in volume is particularly striking when considered in relation to the amount of growing stock left after thinning. Thus, the heavily thinned stand, with only 55 per cent of the volume of the unthinned stand, not only produced a larger total volume of wood, but on a percentage basis grew more than twice as fast.

TABLE 30.—*Results of thinning in an even-aged, 25-year-old stand in the mixed-hardwoods type of the Allegheny hardwoods-pine-hemlock region, 1914–1925*

Character of plot	Trees per acre				Diameter of average tree			
	Before thinning	After thinning			Before thinning	After thinning		
		1914	1919	1924		1914	1919	1924
	Number	*Number*	*Number*	*Number*	*Inches*	*Inches*	*Inches*	*Inches*
Unthinned	652	652	620	580	4.62	4.62	5.32	5.91
Lightly thinned	660	376	376	376	3.70	4.80	5.74	6.34
Heavily thinned	760	344	332	328	3.97	4.68	5.85	6.90

Character of plot	Volume per acre				Average annual growth per acre			
	Before thinning	After thinning			1914–1919		1919–1924	
		1914	1919	1924				
	Cords	*Cords*	*Cords*	*Cords*	*Cords*	*Per cent*	*Cords*	*Per cent*
Unthinned	17.4	17.4	22.0	26.6	0.90	5.2	0.93	4.2
Lightly thinned	19.1	10.9	15.6	22.1	.94	8.6	1.31	8.0
Heavily thinned	20.9	9.5	14.3	22.6	.96	10.1	1.67	11.7

That thinnings may also yield an immediate financial return is indicated by the experience already cited, of the community church in New Jersey which made a thinning in a badly crowded 20-acre wood lot of mixed hardwoods and realized a net profit of $57 per acre, leaving a stand of thrifty, fast-growing trees, whose final development will be much more rapid and will result in a final crop probably more than double what it would otherwise have been.

As in the other hardwood types, slash disposal is not necessary to obtain satisfactory reproduction. Of far greater importance is the prevention of grazing, which does much damage to young growth and tends toward soil erosion.

YIELDS

No figures of yield are available for this type. It is probably safe to assume, however, that the production of fully stocked stands will at least equal and probably exceed that in the oak type given on page 89. Measurements of fully stocked stands of ash on good sites, chiefly in the Central States, show considerably higher yields (*45*).

PINE-HEMLOCK TYPE

The pine-hemlock type occurs chiefly in the more rugged parts of south-central New York and north-central Pennsylvania, although it also extends southward along the Alleghenies and other near-by mountain ranges. Northern white pine and eastern hemlock, occasionally pure but more commonly in varying degrees of mixture, are the characteristic species. (Pl. 19.) Hardwoods are often present and may include any of the species typical of the northern hardwoods or mixed hardwoods. In fact, the type tends to blend with the northern-hardwoods type toward the north and at higher eleva-

tions, and with the mixed-hardwoods type and oak type toward the south and at the lower elevations.

The pine-hemlock type was originally the most important type commercially in northern Pennsylvania, and furnished the bulk of the lumber cut in that State during the early days. In places the stands were so dense and cast such a heavy shade as to acquire the nickname of the "black forest." These have been steadily logged until to-day only a few remnants of the virgin forest are left. Moreover, lumbering has often been followed by fire, with the result that extensive areas once occupied by valuable pine and hemlock are now covered by comparatively worthless aspen, pin (fire) cherry, and "scrub" oak.[7]

METHODS OF CUTTING

Wherever adequate reproduction is already present, either in virgin or second-growth stands, clear cutting will give satisfactory results. Where it is not present, as is likely to be the case in fully stocked stands, the shelter-wood method should be used. The first cutting is fairly certain to induce good reproduction of pine and hemlock, and also of such hardwoods as may be represented, and can usually be followed in from 5 to 10 years by the removal of the remaining stand. Care should be taken in the final cutting to avoid injury to the conifers and at the same time to cut back as much as possible the advance growth of hardwoods, in order to give the former every opportunity for development.

Immature stands can be increased considerably in value by cleanings and thinnings similar to those recommended for the pine and hardwoods type. White pine should be favored as the fastest growing and most valuable species, although some admixture of hemlock and hardwoods is advisable as a means of improving the quality of the pine. Hemlock is an even more desirable associate than hardwoods, because it demands less room, grows less rapidly in height, and is able to persist for many years under even moderately dense shade. There is, therefore, less danger that it will overtop or crowd out the pine, while at the same time it is equally effective in bringing about natural pruning. Intensive measures are, however, less practicable than in the white pine region, because of the usual occurrence of the pine and hemlock type in sparsely settled districts with poor markets for fuel wood.

The coniferous slash resulting from either clear cutting or shelter-wood cutting is usually so abundant and forms such dense piles as to interfere seriously with the establishment of reproduction over a large part of the area. Both pine and hemlock tops should, therefore, be gotten out of the way by burning, preferably in small piles as the logging proceeds and when the woods are moist enough to prevent fire from running. Thinnings result in comparatively little slash where the material removed can be utilized and even where it can not, burning is hardly feasible because of the danger to the remaining stand. Any special disposal of hardwood slash is also unnecessary.

[7] Although bear oak is the standard name for *Quercus ilicifolia* as given in the Check List of the Forest Trees of the United States (47), that species is so generally known as "scrub" oak throughout the Northeast that that common name is used in this bulletin.

YIELDS

Accurate figures on yields are not available, but in well-stocked stands these can be expected to correspond fairly closely to those in the white pine type already given.

OTHER TYPES

On the extensive areas now occupied by aspen, pin (fire) cherry, and scrub oak, the great problem is to hasten the reversion of this temporary transition type to the original pine and hemlock. The problem is similar to that offered by the gray birch type in the white pine and oak region, but is more difficult because of the fact that market conditions usually make the profitable utilization of the inferior species impracticable. Where natural reproduction of desirable species is present, it will ordinarily succeed eventually in reclaiming the area; but the process can be hastened by lopping back the overtopping inferior hardwoods at a probable cost of from $2 to $5 per acre. Where natural reproduction is not present, the only way to restore the original type within a reasonable time is by the still more expensive method of planting and subsequent cleaning.

The following types are discussed at length under the region indicated, and the suggestions for handling them given there apply equally well in the Allegheny hardwoods-pine-hemlock region: Northern hardwoods type, spruce and northern hardwoods region; white pine type, white pine region; and oak type, oak region.

PINE AND OAK REGION

The pine and oak region is characterized by either pure or mixed stands of pines and oaks. The different species vary rather widely in abundance in different parts of the region, but pitch pine and scrub oak are usually prominent. In New England post oak is also a characteristic species. In New Jersey shortleaf pine, white oak, and black oak are common, and more or less backjack oak, post oak, and scarlet oak are found. Southern white cedar is locally abundant in swamps along the coast. The principal types are pine, pine-oak, oak, and southern white cedar.

The region occupies Cape Cod, southern Long Island, and southern New Jersey. There are a few communities which certain types of intensive farming have made very prosperous, but the light soils have prevented general agricultural development, and the population is much less dense than in the adjacent oak region. Great strides have been made in recent years toward control of the forest fires which formerly were frequent and had reduced both vegetation and soil to very poor condition.

PINE TYPE

The pine type in the pine and oak region is characterized on Cape Cod and Long Island by pitch pine, and in southern New Jersey by pitch pine, or shortleaf pine, or both species in mixture. On burned-over areas scrub oak is nearly always abundant. Various other oaks are occasionally present. The type is confined chiefly to the poorest, dryest sands. Repeated burning has in-

creased the original representation of pitch pine and scrub oak and has left the majority of stands in poor condition, with slow-growing, unhealthy, deformed trees. Pine has been able to survive partly because its light, wind-blown seeds give it an advantage in restocking cut-over areas, but still more because of the ability of both pitch pine and shortleaf pine to sprout after cutting or fire. The sprouts are, however, usually weak unless they come from such small stems as to be classed as seedling sprouts. Sprouts from larger stumps, although they live long enough to produce fertile seed, seldom make thrifty trees of any size.

METHODS OF CUTTING

A fair amount of pine reproduction is usually present in moderately open stands from which fire has been kept out. Here, clear-cutting will afford the full light necessary for the best development of both pitch pine and shortleaf pine. In dense stands, on the other hand, seedlings are usually scarce because of their intolerance of overhead shade and their inability to start on a thick layer of pine needles. Here, a heavy shelter-wood cutting which removes at least 50 to 70 per cent of the crown cover will stimulate reproduction by admitting ample light and hastening the decomposition of the needle litter (*2*). The remaining stand can be cut as soon as the new crop is well established.

Seed trees, although somewhat less certain to produce fully stocked stands, can often be used in place of the shelter-wood method with satisfactory results. Because of the great danger of fire, they can also be left to good advantage after clear-cutting or after the final shelter-wood cutting, even where plenty of seedlings are already present, in order to afford a supply of seed for restocking the area in case the existing crop should be destroyed by fire. There should be from 5 to 10 windfirm trees per acre with sufficient crown to produce abundant seed. Where shortleaf pine is present, it should be favored over pitch pine because of its better form and superior wood.

Where pine tops can be utilized for fuel, the quantity of slash left is so small that no disposal is necessary aside from scattering as uniformly as possible. Elsewhere, the quantity may be sufficient to warrant burning, particularly in view of the extremely high fire hazard. Burning in this type is itself more or less hazardous, however, and should be done, if at all, when the danger that fire will escape is least, as for example in wet weather, when snow is on the ground, or after nightfall. If burning is not done, lopping and scattering will hasten the decay of slash and reduce its interference with reproduction.

Cleaning is unnecessary in young stands of either pitch pine or shortleaf pine, both of which on the dry soils characteristic of this type are able to hold their own with such hardwoods as may be present. Thinning is, however, advisable in the crowded stands which sometimes occur on unburned areas, provided the material removed can be marketed without loss. Such thinnings should be made as early as possible and never later than 40 or 45 years of age. Dominant, healthy trees, particularly of shortleaf pine, should be favored by the removal of poorly formed, defective, and suppressed

IN THE MIXED-HARDWOODS TYPE

A, A fairly mature stand with good advance growth; B, an improvement cutting in a similar stand. The absence of reproduction is probably due to grazing

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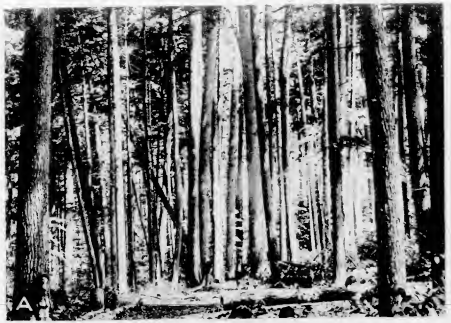
IN THE MIXED-HARDWOODS TYPE

A, A fairly mature stand with good advance growth; B, an improvement cutting in a similar stand. The absence of reproduction is probably due to grazing.

A PROFITABLE THINNING OPERATION

This thinning (A) yielded a net profit of $57 per acre and left the stand in better condition than before (B).



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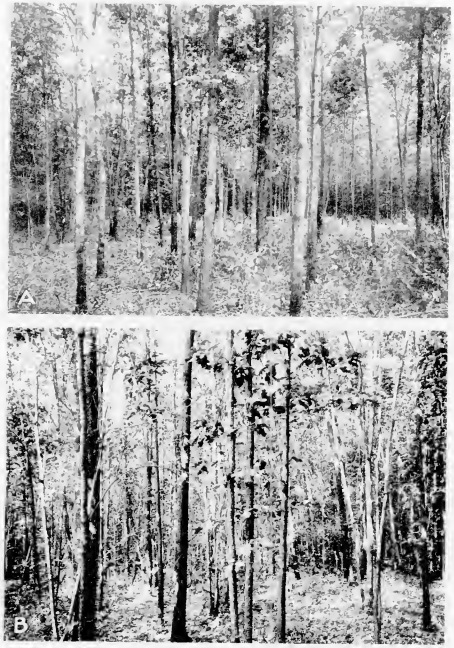
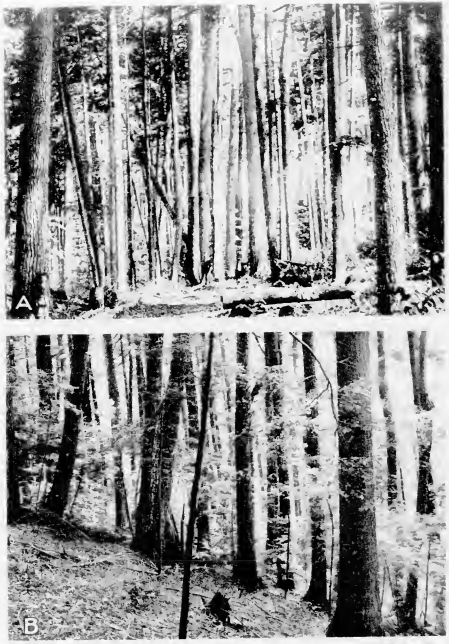
IN THE PINE-HEMLOCK TYPE

A, A mature stand of pure white pine in Clearfield County, Pa.; B, a stand of practically pure hemlock, with hemlock reproduction, in Otsego County, N. Y.



A PROFITABLE THINNING OPERATION

The thinning [illegible] yielded a net profit of $57 per acre and left the stand in better condition than before [illegible]



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PROFITABLE THINNINGS IN THE PINE AND OAK REGION

A, In this stand in the pine type nearly half of the volume was removed in a thinning that brought a net profit of $55 per acre and left the stand in excellent condition for future growth; B, thinning in this stand in the pine and oak type netted $5 per acre and also paid for burning the slash. (Photographs by courtesy of the N. J. Dept. Conservation and Development.)

SOUTHERN NEW JERSEY THINNINGS

A, An area in southern New Jersey from which the oak has been cut clear and the brush burned. Five hundred to six hundred pines per acre will be planted and about five years later the oak sprouts will probably be cut back to favor the pine. B, A 40 to 50 year old stand of southern white cedar after a thinning which yielded a net profit of about $75 per acre. (Photographs by courtesy of the N. J. Dept. Conservation and Development.)

PROFITABLE THINNINGS IN THE PINE AND OAK REGION

A, In this stand in the pine type nearly half of the volume was removed in a thinning that brought a net profit of $35 per acre and left the stand in excellent condition for future growth; B, thinning in this stand in the pine and oak type netted $5 per acre and also paid for burning the slash. (Photographs by courtesy of the N. J. Dept. Conservation and Development.)

SOUTHERN NEW JERSEY THINNINGS

A, An area in southern New Jersey from which the oak has been cut clear and the brush burned. Five hundred to six hundred pines per acre will be planted and about five years from the time sprouts will probably be cut back to favor the pine. B, A 40 to 50 year old stand of southern white cedar after thinning which yielded a net profit of about $25 per acre. (Photographs by courtesy of the N. J. Dept. Conservation and Development.)

trees, together with enough larger ones to give them plenty of room for development. The quantity of material removed and the stands thus obtained, in actual thinnings of fully stocked, crowded, but thrifty stands of shortleaf pine in New Jersey (2), are given in Table 31.

TABLE 31.—*Data on thinnings in fully stocked, crowded, thrifty stands of shortleaf pine in New Jersey*[1]

Average age of stand (years)	Degree of thinning	Trees per acre		Average diameter of trees		Volume per acre	
		Before thinning	After thinning	Before thinning	After thinning	Before thinning	After thinning
		Number	*Number*	*Inches*	*Inches*	*Cords*	*Cords*
15	Light	2,000	1,200	3.0	3.5	12	9
15	Moderate	2,000	1,000	3.0	4.0	12	8
20	Light	1,800	900	3.5	4.5	18	15
20	Moderate	1,800	750	3.5	5.0	18	13
25	do	1,400	600	4.0	6.0	25	18
25	Heavy	1,400	500	4.0	6.5	25	15
35	Moderate	800	400	5.0	7.0	30	20
35	Heavy	800	300	5.0	7.5	30	17
45	Moderate	450	225	6.0	8.0	35	24
45	Heavy	450	175	6.0	8.5	35	21

[1] Figures are for trees 2 inches and more in diameter at breastheight.

Thinnings not only improve the condition of the stand and result in increased growth, but under favorable market conditions may prove decidedly profitable. (Pl. 20.) The State forester of New Jersey (2), for example, reports a 35-year-old stand of shortleaf and pitch pine from which 6 cords of wood per acre were removed at a profit, with the probable result of increasing the yield at 50 years of age from about 15,000 board feet to at least 20,000 board feet per acre.

YIELDS

No figures for yields are available other than those given in Table 31, but they will undoubtedly run much lower than in the white pine type. Properly stocked stands should, however, yield at least 20,000 to 25,000 board feet per acre at 50 or 60 years of age.

PINE-OAK TYPE

The pine-oak type resembles the pine type except for the much larger proportion of oak. This comes in more freely on the slightly better, although still poor soils, and may form 50 per cent or even more of the stand. On Cape Cod, post oak is the principal species of oak, while in New Jersey black, blackjack, white, chestnut, post, and scarlet oaks are more common. Scrub oak frequently appears after fires in both parts of the region.

On the whole, the mixture is usually a desirable one. Pine, especially shortleaf pine, produces more lumber, but oak helps to improve the quality of the soil and yields more and better cordwood from thinnings. If fire is kept out, the natural tendency is for the oak to increase in abundance.

Clear cutting results in the vigorous production of oak sprouts, which are likely to suppress such advance growth of pine as may already be present. (Pl. 21, A.) The most effective way to maintain or increase the proportion of conifers is to plant a few hundred pines in the openings among the stumps after clear cutting and to give them an opening to develop by cutting back the competing hardwoods. Whether or not this procedure costs more than it is worth depends on how well stocked a stand of desirable hardwoods might otherwise be expected on the area if no cutting were done.

Thinnings in crowded stands are advisable wherever there is a market for the product. In general, the better trees should be retained, irrespective of species, but with a tendency, as between two equally good trees, to favor pine, particularly shortleaf pine.

Mention should be made here of the pitch pine-chestnut oak combination which commonly occurs on the mountain slopes of northwestern New Jersey and eastern and southern Pennsylvania, and which has already been referred to in the discussion of the oak type. This combination differs from the pine and oak type of New Jersey in that shortleaf pine is absent and that chestnut was formerly abundant. It also occurs on better soils, and produces larger yields. Pitch pine probably attains its best development in this combination, which is often recognized as a separate type and should be distinguished from the pine-oak type of the coastal plain.

SCRUB-OAK TYPE

The scrub-oak type is characterized by the predominance of scrub oak, and occurs on areas from which other species have been largely eliminated by successive fires. It is common not only throughout the pine and oak region, but also in eastern Pennsylvania, where it is the prevailing type in the anthracite coal fields, and in parts of the bituminous coal fields.

Scrub oak sprouts so vigorously that it is able to perpetuate itself indefinitely on areas that are repeatedly burned. If fire is kept out, however, various other oaks, pitch pine, and in New Jersey shortleaf pine, gradually creep in and replace it. With adequate protection from fire the type is, therefore, a strictly temporary one, although if there are no near-by seed trees of more valuable species it may be many decades before these are able to obtain even a foothold.

Where pine and better oaks are coming in naturally these species can be hastened by cutting back the scrub oak. Elsewhere conversion of the type to a more valuable one can be effected by burning followed by the planting of shortleaf pine. At least one subsequent cleaning is likely to be necessary to insure the establishment of the planted trees. Either of these methods of converting the scrub-oak type to something better will probably cost from $8 to $15 per acre. Whether this investment can be justified in view of the probable returns is perhaps open to question. The scrub-oak type may, therefore, be one where intensive forestry is at present impracticable and where, aside from keeping out fire, nature must be allowed to take its course.

OAK TYPE

The oak type in this region usually differs from that in the oak region in containing a smaller proportion of other hardwoods. The method of treatment can be the same, but yields are apt to be somewhat less because of the poorer soils.

SOUTHERN WHITE CEDAR TYPE

In the Northeast the southern white cedar type occurs only in the swamps of southern New England and the coastal plain of New Jersey. It is characterized by the predominance of southern white cedar, which is usually pure, although occasionally mixed with red maple and other scattering hardwoods.

Many areas formerly occupied by the type have been converted after cutting into cranberry bogs. Although of restricted occurrence, it is locally of considerable importance because of the high value of southern white cedar wood. (Pl. 21, B.) Its management will be discussed in a bulletin now in preparation.

PLANTING

Clear cutting of mature stands followed by planting of the cut-over areas constitutes a possible method of starting a new crop in any type. Its chief merits are simplicity and reasonable certainty of success. On the other hand, it is expensive; fail places often occur which must be filled by replanting; and cleanings are usually necessary to prevent suppression of the planted trees by undesirable species. Unless the nursery stock used comes from locally produced seed, there is also danger that it will not be so perfectly adapted to the site as native seedlings are. Wholesale planting after cutting is, therefore, seldom advisable save as a last resort.

In most cases the wisest course is to get the best possible natural reproduction by one of the methods described, and to supplement this by planting the unstocked patches which are apt to occur even with the most careful handling. Since the total area involved is usually not large, planting offers an effective and not unduly expensive means of making these productive and thereby increasing the final yield. There is no doubt that planting, which has so far been resorted to mainly for reforesting areas without tree growth, might advantageously be used much more widely in connection with natural reproduction for the growing of full timber crops.

Planting for this purpose should, of course, be done in accordance with the general principles outlined in connection with the reforestation of completely idle lands (pp. 20–24). The species used in any given type should ordinarily be one or more of those which it is desirable to favor in the natural reproduction. Such hardy and valuable conifers as white pine, Norway pine, and Norway spruce can, however, often be planted to advantage on sites to which they are adapted even though they were not present in the original stand. Wherever white pine is used it must be protected from the blister rust by the eradication of currant and gooseberry bushes.

Planting should be done if possible soon after the removal of the previous crop so as to enable the planted trees to develop on even

terms with the natural reproduction. After the new stand is well started, there is little use in planting openings which do not have a diameter equal to at least twice the height of the surrounding trees. Cleanings to assure the planted trees ample opportunity for free development are even more important than with natural reproduction because of the greater investment represented in the former.

Planting may also be used to convert a comparatively worthless type into one of valuable species. Specific examples which have already been mentioned are the replacement of gray birch by white pine and of scrub oak by shortleaf pine or loblolly pine. This is, of course, much more expensive than the supplementing of desirable reproduction, and one or two cleanings will usually be necessary to assure the satisfactory development of the planted trees.

SUMMARY OF MEASURES NECESSARY TO PRODUCE FULL TIMBER CROPS

In addition to the adequate protection of all forest land from fire, insects, and disease, the production of full crops of timber requires such treatment of existing forests as will insure the best possible yield of desirable species. Silviculture is so essentially a local matter that this treatment will vary more or less widely for each forest type and even for each individual stand. Certain broad principles of rather general application can, however, be recognized.

REPRODUCTION CUTTINGS

Mature stands in any type should be harvested in such a way as to assure the perpetuation of the forest. Where advance growth of desirable species is already present, this can be done by the clear cutting of all merchantable material. Where advance growth is not present, reproduction can be stimulated by the use of the shelterwood method, under which about half the stand is removed in a first cutting and the remainder 5 to 10 years after the new crop is well established. The shelter-wood method can also be used to bring in desirable species that are not well represented in the advance growth, as for example in the white pine type, where hardwood seedlings are apt to be much more abundant than white pine. Selection cutting, or the removal of occasional trees or groups of trees in different parts of the stand, is often desirable in uneven-aged stands and particularly in farm wood lots. Where satisfactory natural reproduction does not follow cutting, planting can advantageously be undertaken, provided the work is done soon after the final removal of the mature stand.

Care should be taken in logging to avoid injury to all young trees which should form part of the next crop. On the other hand, inferior species and poorly formed, unthrifty trees, both in the residual stand and in advance growth, may well be cut at the time of logging to favor those of more promise. In the white pine types it is even worth while to make a special effort to cut back the young hardwoods in order to give the white pine seedlings a better chance for development. In practically all types logging damage to conifers is to be particularly avoided.

SLASH DISPOSAL

The dense piles or windrows of slash which are commonly left after logging often cover a sufficient area to interfere seriously with the establishment of fully stocked stands. Wherever market conditions permit, this difficulty can be largely avoided by utilizing as much as possible of the slash for fuel and scattering the rest. Coniferous slash is particularly dangerous because it packs down closely and decays slowly. In places where it is dense and utilization is impracticable, disposal of coniferous slash by burning, preferably as logging proceeds, is, therefore, advisable. Hardwood slash is so much more open and decays so much more rapidly that no special disposal is generally necessary.

IMPROVEMENT CUTTINGS

Cultural measures are fully as important for young stands as is their establishment. The first work of this sort can be done to excellent advantage when the new crop is only a few years old. It should aim to improve the composition and quality of the stand by cutting back the undesirable species and individuals. This will give a better opportunity for the development of the more desirable elements which might otherwise be badly suppressed or completely eliminated. Because of their slow initial growth, conifers particularly need to be favored in this way. Two or even three cleanings may, in fact, be necessary to enable conifers to reach a height where they can hold their own with the more aggressive hardwoods.

Very similar improvement cuttings can be made as soon as the stands are old enough so that the material removed can be used for fuel. Near good markets this will ordinarily be between 20 and 30 years of age. At about the same time, well-stocked stands become so crowded as to require thinning in order to prevent a falling off in their rate of growth. Trees which are undesirable from the standpoint of species, form, vigor, or position in the stand should be removed, together with enough of the better trees to give those that are left ample growing space. The thinning can then be repeated when the stand has again become crowded, say in 5 to 10 years. Frequent light thinnings are better than infrequent heavy ones. By maintaining the rate of growth of the stand and concentrating this growth on the best trees, thinnings increase the final return and also yield an intermediate profit from the material removed.

GRAZING

Cattle, horses, and sheep do so much damage to young hardwoods that they should be excluded from stands of all ages in which hardwoods are to be favored. On cut-over areas where conifers are to be favored, limited grazing may, on the other hand, be an advantage by helping to reduce competition from the hardwoods. Although it will usually result in some injury to the conifers from trampling, its chief effect is to serve as a very crude sort of cleaning.

YIELDS

Yields of fully stocked natural stands indicate the minimum that can reasonably be expected under intensive forest management.

With properly handled cuttings, cleanings, and thinnings in the new forest it should be possible to exceed these yields both in the volume and quality of the final product. Figure 26 shows the mean annual growth in cubic feet of fully stocked natural stands of several

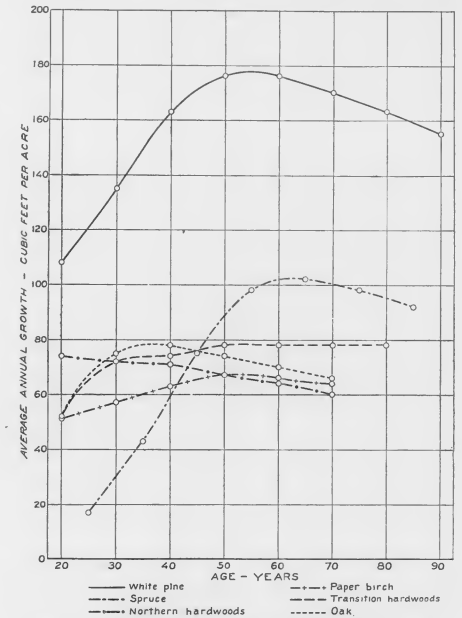

FIGURE 26.—Average annual growth of various forest types on the best sites

representative types on the best sites. While the figures are not wholly comparable, they give some idea of relative productivity. The great superiority of white pine and the practical uniformity of the hardwood types are particularly striking.

TREATMENT BY FOREST TYPES

SPRUCE

In pure stands of spruce clear cutting is advisable where advance growth is abundant. Where advance growth is scanty, a third to a half of the crown canopy should be removed first and the remainder of the stand a few years later, after the reproduction following cutting has become well established. On steep slopes, however, partial cutting is so likely to result in serious windfall that the only real alternative to clear cutting is to leave the stand intact as a protection forest.

In mixed stands of spruce and northern hardwoods, clear cutting of both conifers and hardwoods to the lowest merchantable diameter is desirable, provided the advance growth of spruce and balsam fir is abundant. Where such growth is lacking, or where the hardwoods are not merchantable, there is little hope of maintaining a large proportion of conifers in the new stand by reproduction cuttings alone.

Special care should be taken in all logging operations to do as little injury as possible to advance growth of spruce and balsam fir. Dense conifer slash interferes seriously with the establishment and development of reproduction and can advantageously be disposed of by burning in small piles as cutting proceeds during fall or winter logging. In spring and summer logging, burning must be deferred until late fall or early winter, when heavy rains or snows make it safe.

The development of young spruce and balsam fir after logging can be greatly aided by cutting back the competing hardwoods at a cost of about $2 an acre. The young conifers can also be favored by the girdling of large hardwoods which would otherwise suppress them. This operation can be performed at a cost of $1.25 to $1.50 an acre. Girdling should be limited strictly to hardwoods which are actually interfering with the development of good coniferous reproduction, and which, because of poor quality or inaccessibility, are practically certain to have no commercial value in the near future. The thinning of overdense young stands is desirable wherever the value of the material removed will pay for the cost of the thinning.

Damage from the spruce bud worm can be lessened by reducing the proportion of balsam fir and by cutting out infestations as soon as they appear.

Yields per acre in pulpwood at 70 years run from 36.5 cords on poor sites to 69.7 cords on good sites. Board-foot yields are relatively low because of the small diameters characteristic of fully stocked stands of spruce. They range from 8,800 feet per acre on poor sites to 31,800 on good sites at 70 years.

NORTHERN HARDWOODS

Old-growth stands of northern hardwoods can ordinarily be handled to best advantage by cutting all merchantable trees down to an average diameter of about 12 or 15 inches. This will permit the establishment of new reproduction and the development of the re-

maining stand, which can later be removed in successive partial cuttings. Clear cutting, which is satisfactory wherever advance growth is abundant, is seldom feasible economically because of the absence of a market for the trees. When practiced, it should remove the stand as completely as possible, including small saplings.

Second-growth stands are usually even aged and near enough a market to permit complete utilization. When well stocked they have a rather uniform, dense crown cover which tends to prevent abundant reproduction. Under these conditions the removal of the stand in two cuttings by the shelter wood is advisable. Irregular and uneven-aged second-growth stands can be handled by selection cutting.

No special disposal of slash after logging operations is necessary. Grazing of all sorts is highly injurious to hardwood reproduction and should not be permitted in either old-growth or second-growth stands. Cleanings to favor the best individuals of the desired species and thinnings to increase the growth in overdense stands are theoretically desirable but economically impracticable in a large part of the type.

Yields of well-stocked second-growth stands on good sites may run as high in cords as the stand is years old. Although not now common over extensive areas, they should be possible of attainment under intensive forest management. After 60 years of age the total growth increases slowly.

BIRCH-ASPEN

The birch-aspen type characteristically occurs on burned-over land as a transition type which the owner is only too glad to have revert to the original type of spruce or northern hardwoods. Since advance reproduction of the more valuable species is usually present, the change back to the original type can most easily be effected by clear cutting the birch and aspen as soon as they reach merchantable size. No special disposal of the slash is necessary. Stands of average density can be expected to yield about 17 to 26 cords per acre at 50 years of age.

WHITE PINE

On good soils white pine attains its best development in mixture with the better hardwoods, such as red oak, white ash, sugar maple, and yellow birch, which do not thrive on poor soils, where pure stands of white pine are usually the objective. In both cases satisfactory reproduction can best be obtained by the shelter-wood method of cutting. The first cutting should remove from 40 to 50 per cent of the crown canopy and, if practicable, should be made while there is no snow and the litter and humus may be torn up as much as possible. The remainder of the stand should be cut clear when the reproduction resulting from the first cutting is from 4 to 6 years old. On areas where the soil is light and the stand is more or less uneven aged, a heavier first cutting can be made to favor the smaller trees, and the second cutting can be deferred a few years longer. Seed trees, while occasionally satisfactory, are a less dependable method of reproduction than the shelter-wood method.

The pine slash resulting from cutting in the white pine types is usually heavy, decays slowly, and interferes seriously with the establishment of well-stocked stands. Where market conditions do not permit its sale for fuel it should be burned in small piles or in windrows. This can be done at a cost of from $0.50 to $1.25 for every thousand board feet of timber cut. No special disposal of hardwood slash is necessary.

Cleanings to free young white pines and desirable hardwoods from suppression by less desirable hardwoods, such as red maple, gray birch, and aspen, are very important. The "weed" species should ordinarily be cut back when they are about 3 to 5 years old and 5 to 8 feet high. On good soils a second cleaning will usually be necessary in about five years when the hardwoods will again be overtopping the pine. The total cost may run from $2 to $8 per acre. The limited grazing of cattle or sheep, which browse on the hardwoods, tends to favor the pine, and thus to serve as a crude form of cleaning.

Thinnings of overdense stands should ordinarily be made by the time the trees are 20 to 25 years, and may be repeated at 5 to 10 year intervals. Spaces of 3 to 5 feet between the crowns of the trees left will ordinarily be completely filled within five years. Judicious thinning may readily increase the volume of the stand 20 per cent as compared with unthinned stands.

White pine should be protected from the blister rust by the complete eradication of cultivated black-currant bushes and by the removal of all other currant and gooseberry bushes, both wild and cultivated, within 900 feet of adjacent stands. Where the pales weevil is a serious menace, the only real safeguard is to obtain natural reproduction of white pine in such abundance that a loss of 50 to 75 per cent will still leave enough seedlings to form a satisfactory stand. Pine plantations can not safely be set out on cut-over pine areas until the third year after cutting. Some protection can be afforded against serious injury by the white pine weevil by growing white pine in comparatively dense young stands and in mixture with other species, or by removing infested leaders and either burning them or placing them in tight barrels covered by a wire mesh.

Yields of fully stocked second-growth stands of white pine at 60 years of age range from 33,600 board feet per acre on poor sites to 60,200 board feet on good sites.

TRANSITION HARDWOODS

In even-aged stands satisfactory natural reproduction in the transition-hardwoods type can ordinarily be obtained either by clear cutting or by shelter-wood cutting. Clear cutting is preferable where advance reproduction is abundant, shelter-wood cutting where it is scanty. The first of the two shelter-wood cuttings should take 40 to 50 per cent of the crown canopy, the remainder being removed as soon as seedling reproduction has become well established. In uneven-aged stands selection cuttings which remove only a few trees at a time and thus give the new stand a chance to come in gradually are both practicable and desirable.

No disposal of the slash is necessary. Grazing of either cattle or sheep should be entirely excluded.

Clearings that favor the best individuals of desired species will improve the quality and composition of the stand. Thinnings are advisable from 20 years on, wherever there is a market for the material removed.

Yields run at 60 years of age from about 40 cords per acre on average sites to about 55 cords on good sites. At the same age the lumber content varies from 8,700 board feet on average sites to 15,600 board feet on good sites, with additional cordwood.

GRAY BIRCH

The chief object of cutting in the gray birch type is to hasten its reversion to a forest of more valuable species. This can be done by clear cutting as soon as the stand reaches merchantable size, since this will allow the advance reproduction of white pine and desirable hardwoods, which is ordinarily present, to take possession of the area. Subsequent clearing may be necessary to enable the advance growth to hold its own with the vigorous sprouts from the stumps of the cut trees. Where advance growth is not present, conversion to the white-pine type can be effected by planting, followed by removal of the gray birch stand three to eight years later. The slash is light and decays quickly, so that no disposal is necessary.

Yields are about 20 cords per acre at 25 to 30 years of age, after which the short-lived stands break up rather rapidly.

OAK

In even-aged stands clear cutting is advisable where advance growth is abundant, shelter-wood cutting where it is scanty. The first cutting should leave about half of the stand in the form of evenly distributed thrifty trees of desirable species. These can then be cut clear in four to eight years after the reproduction resulting from the opening of the stand is well established. In uneven-aged stands reproduction can be obtained by the selection method of cutting, which retains some merchantable material constantly on the ground. This method of cutting is particularly adapted to the small wood lot and can often be combined to advantage with improvement cuttings.

No special disposal of slash is necessary. Grazing should be completely prohibited, since it is almost certain to interfere seriously with hardwood reproduction.

The quality of young stands can be improved by cutting back poorly formed and defective trees of all species, dominant individuals of inferior species which are overtopping desirable species, and dominant sprouts which are overtopping more desirable seedlings or seedling sprouts. Clearings of this sort should ordinarily be made three to five years after the final cutting of the stand and may need to be repeated a few years later. The cost should not exceed $1 to $4 per acre. In dense stands frequent light thinnings are desirable after the stand is 20 to 30 years old. Where these are not practicable because of poor market, a heavy thinning can advantageously be made at 35 to 40 years of age.

Yields at 50 years of age range from 29 cords per acre on poor sites to 48 cords per acre on good sites. At 75 years the lumber yield averages 7,400 board feet on poor sites and 17,100 board feet on good sites.

HARDWOOD-SWAMP

Clear cutting is necessary in the hardwood-swamp type because of the danger of windfall. Satisfactory restocking usually takes place from seedlings already on the ground and from the vigorous sprouts, particularly of red maple, which follow cutting.

MIXED HARDWOODS

The mixed-hardwood type resembles the oak type so closely in its reproduction and development that it can be handled in practically the same way. Clear cutting or shelter-wood cutting is satisfactory in even-aged stands, depending on whether or not advance growth is present; selection cutting in uneven-aged stands. No slash disposal is necessary. Clearings and thinnings are both desirable where market conditions permit. Yields are about the same as in the oak type.

PINE-HEMLOCK

Where adequate reproduction is already present, either in virgin or second-growth stands, clear cutting will give satisfactory results. Where it is not present, the shelter-wood method should be used. In the second cutting, which should come 5 to 10 years after the first, care should be taken to avoid injury to the young conifers and at the same time to cut back the advance growth of hardwoods. Coniferous slash should be burned in small piles, preferably as the logging proceeds, and when the woods are moist enough to prevent fire from running. Clearings and thinnings are desirable but usually less practicable than in the white pine type.

PINE (PITCH AND SHORTLEAF)

Clear cutting is advisable in moderately open stands where a fair amount of pine reproduction is present. In dense stands with few seedlings a heavy shelter-wood cutting which removes 50 to 70 per cent of the crown canopy will stimulate reproduction, and the remainder of the stand can be removed after the reproduction is well established. Seed trees sometimes give good results and can be used to advantage in connection with both clear cutting and shelter-wood cutting, in order to afford a supply of seed for restocking the area in case the young stand should be destroyed by fire. There should be 5 to 10 windfirm trees per acre with sufficient crown to produce abundant seed. Shortleaf pine should be favored against pitch pine. Where the pine tops can not be used for fuel they should be burned in small piles or lopped and scattered. Thinnings are usually unnecessary because of the absence of hardwood competition. Thinnings in dense stands should be made as early as possible and never later than 40 or 45 years of age.

PINE-OAK

In the pine-oak type clear cutting results in so vigorous a reproduction of oak sprouts that any advance growth of pine that is present is likely to be suppressed. The proportion of pine can be maintained by planting several hundred pine trees in the openings among the stumps after the clear cutting, and then cleaning back the competing hardwoods. Thinnings are desirable where there is a market for the product, and should aim to favor pine.

SCRUB OAK

If fire is kept out of the scrub oak type various other oaks, pitch pine, and in New Jersey shortleaf pine, gradually creep in and replace it. This process can be hastened and the growth of the invading species accelerated by cutting back the scrub oak. Elsewhere conversion of the type to a more valuable one can be affected by burning followed by the planting of shortleaf pine. At least one subsequent clearing is likely to be necessary to insure the establishment of the planted trees.

CONCLUSION

The next step beyond the practice of good silviculture is to handle a forest property so as to obtain a regular income from it. This necessitates a knowledge of the amount of standing timber, of forest capital, and of its rate of growth. On the basis of this knowledge, logging operations can be so planned as to maintain a constant income from the forest capital by cutting during any given year or period of years only the quantity of timber grown during that period.

The production of full timber crops often requires an outlay that could be avoided by letting nature take its course; but this outlay is reasonably sure to be repaid many fold by the increased value of the final product. This is particularly true in the Northeast, where favorable climatic and soil conditions, desirable trees, and excellent markets combine to make timber growing a profitable business.

LIST OF THE TREES AND SHRUBS REFERRED TO IN THIS BULLETIN

COMMON NAME	SCIENTIFIC NAME
Ash, black.	*Fraxinus nigra.*
Ash, white.	*Fraxinus americana.*
Aspen.	*Populus tremuloides.*
Aspen, largetooth.	*Populus grandidentata.*
Basswood.	*Tilia glabra.*
Beech.	*Fagus grandifolia.*
Beech, blue.	*Carpinus caroliniana.*
Birch, gray.	*Betula populifolia.*
Birch, paper.	*Betula papyrifera.*
Birch, river.	*Betula nigra.*
Birch, sweet.	*Betula lenta.*
Birch, yellow.	*Betula lutea.*
Butternut.	*Juglans cinerea.*
Cedar, northern white.	*Thuja occidentalis.*
Cedar, southern white.	*Chamaecyparis thyoides.*
Cherry, black.	*Prunus serotina.*
Cherry, pin (fire).	*Prunus pennsylvanica.*
Chestnut.	*Castanea dentata.*
Dogwood.	*Cornus florida.*
Elm, American.	*Ulmus americana.*
Fir, balsam.	*Abies balsamea.*
Gum, black.	*Nyssa sylvatica.*
Hazelnut.	*Corylus americana* and *C. rostrata.*
Hemlock, eastern.	*Tsuga canadensis.*
Hickory, bigleaf shagbark.	*Hicoria laciniosa.*
Hickory, mockernut.	*Hicoria alba.*
Hickory, pignut.	*Hicoria glabra.*
Hickory, shagbark.	*Hicoria ovata.*
Hophornbeam.	*Ostrya virginiana.*
Larch, European.	*Larix europaea.*
Larch, Japanese.	*Larix leptolepis.*
Magnolia, cucumber.	*Magnolia acuminata.*
Maple, mountain.	*Acer spicatum.*
Maple, red.	*Acer rubrum.*
Maple, silver.	*Acer saccharinum.*
Maple, striped.	*Acer pennsylvanicum.*
Maple, sugar.	*Acer saccharum.*
Oak, bear (scrub).	*Quercus ilicifolia.*
Oak, black.	*Quercus velutina.*
Oak, blackjack.	*Quercus marilandica.*
Oak, bur.	*Quercus macrocarpa.*
Oak, chestnut.	*Quercus montana.*
Oak, pin.	*Quercus palustris.*
Oak, post.	*Quercus stellata.*
Oak, red.	*Quercus borealis maxima.*
Oak, scarlet.	*Quercus coccinea.*
Oak, "scrub" (bear).	*Quercus ilicifolia.*
Oak, swamp white.	*Quercus bicolor.*
Oak, white.	*Quercus alba.*
Pine, northern white.	*Pinus strobus.*
Pine, Norway.	*Pinus resinosa.*
Pine, pitch.	*Pinus rigida.*
Pine, Scotch.	*Pinus sylvestris.*

COMMON NAME	SCIENTIFIC NAME
Pine, shortleaf.	*Pinus echinata.*
Poplar, yellow.	*Liriodendron tulipifera.*
Sassafras.	*Sassafras variifolium.*
Serviceberry.	*Amelanchier canadensis.*
Spruce, black.	*Picea mariana.*
Spruce, Norway.	*Picea abies.*
Spruce, red.	*Picea rubra.*
Spruce, white.	*Picea glauca.*
Sycamore.	*Platanus occidentalis.*
Tamarack.	*Larix laricina.*
Viburnum.	*Viburnum* sp.
Walnut, black.	*Juglans nigra.*
Willow.	*Salix* sp.
Witch-hazel.	*Hamamelis virginiana.*

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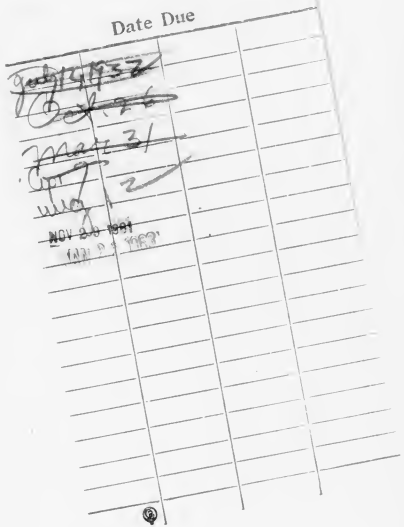

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